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Metal Progress

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Metal Progress

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Ernest E. Thum, Editor

APRIL, 1935 VOL. 27. No. 4

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TIMKEN

Oil-Hardening Alloy Steels

GOOD WILL BASED ON GOOD STEEL

WHEREVER the use of an oil-hardening steel is indicated—as in automobile transmission gears for instance—the superior physical, metallurgical and metallographic characteristics of Timken Oil-Hardening Alloy Steels make possible the production of better parts at lower finished cost.

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Their strength and endurance have been amply proved in service under all sorts of conditions.

Timken Oil-Hardening Alloy Steels are manufactured in the following analyses: carbon-chrome, chrome nickel, chrome vanadium, nickel-molybdenum and 3½% nickel. These analyses are available in several carbon grades to accommodate salt bath or regular hardening practice. Timken metallurgists will gladly cooperate in selecting the analysis and grade most suitable for your requirements.

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TIMKEN ALLOY STEELS

ELECTRIC FURNACE AND OPEN HEARTH • ALL STANDARD AND SPECIAL ANALYSES

Arc Welding Chromium Steel and Iron

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SINCE FUSION WELDING IS A PROCESS that heats metal to various degrees, an adequate understanding of it must be based on knowledge of what a rapidly changing temperature, both up and down, does to metal. This is just as true of the high chromium-iron alloys as it is of steel, the carbon-iron alloy. Consequently this brief discussion must assume that the reader has, or can easily get, information on the fundamental metallurgy of the iron-chromium-carbon system.

Welding with a metal arc is most frequently used. It provides a close control of the carbon content of the deposited weld metal. It is also characterized by a highly localized application of an extremely high welding temperature, so that the thermal gradient from weld to parent metal is quite sharp (unless the latter has been quite strongly preheated); the temperature drops from the melting temperature to about 1000° F. in $\frac{3}{16}$ in. to $\frac{3}{8}$ in. An associated problem is to protect the arc stream of molten metal from the gases of the atmosphere, and to provide foreign materials in the arc stream to stabilize the arc satisfactorily and at the same time produce a slag to protect the deposited weld metal from the air and tend to produce sound metal free from blowholes. This is conveniently accomplished by coatings or coverings which are melted or consumed uniformly with the metal electrode wire.

Covered Electrodes—Two types of electrodes are used. The first is of English origin and is one in which a low carbon steel wire is used, the alloying elements in required amounts being derived from powdered materials in the coating. In the second type, the electrode wire is of the required alloy composition, and the covering performs the functions outlined in the previous paragraph. The latter type of electrode is more generally used.

The coating usually contains an element possessing a preferential affinity for oxygen, such as ferromanganese, ferrotitanium or aluminum. Compounds containing carbon are usually excluded as carbon is readily absorbed by the molten metal, and low carbon is usually a prime requisite for successful corrosion resistance. (However, high carbon is permissible and even desirable in many welds in heat resisting parts.) High carbon in the weld metal also results in impaired ductility. In addition to the deoxidizing ingredients, arc stabilizing and slag forming materials comprise the remainder of the coating—calcium carbonate, calcium fluoride, and silica in varying amounts being favorite ingredients in coatings for stainless electrodes. Potassium or sodium silicate solutions are the binding agent, the semi-liquid mixture being applied to the wire base by either dipping or extrusion; it is then dried and baked.

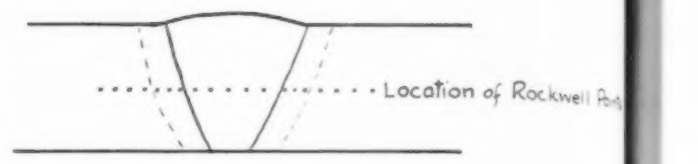
Satisfactory coated electrodes are commercially available for most of the stainless alloys. It should be mentioned that any statement regarding the weldability or non-weldability of any alloy must be considered as possessing limitations. The 28% chromium-irons are usually considered as non-weldable for any important or highly stressed part (a pressure vessel for example) but this alloy may be satisfactorily welded where the service conditions are such that brittleness is of minor importance.

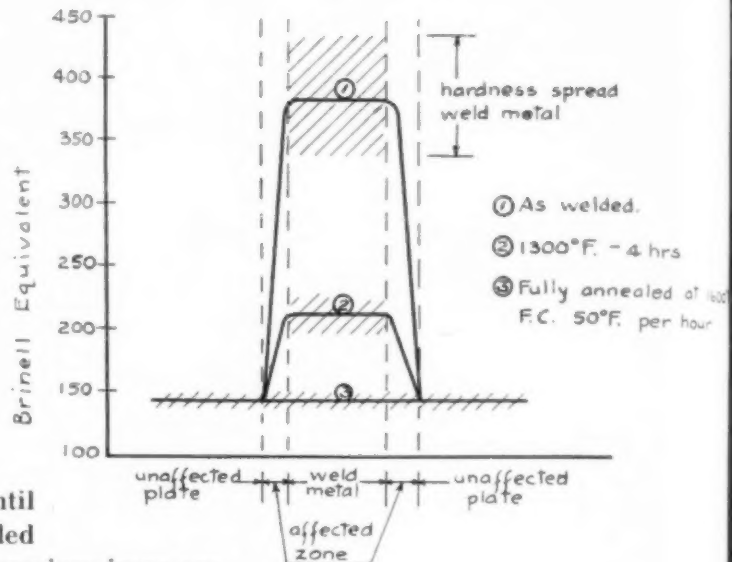
Fortunately, welding technique for the stainless alloys follows good welding practice on plain carbon steel. Some observations, peculiar to

stainless alloy welding, follow.

Electrodes are generally smaller in diameter than plain carbon steel electrodes for welding parts of similar thickness; ⅛ in., $\frac{5}{32}$ in. and $\frac{3}{16}$ in. diameter electrodes are common.

Variation in Hardness of Weld Metal (5% Chromium, 0.5% Molybdenum) as Welded, as Softened, and as Fully Annealed. Hardness on Rockwell machine is converted to Brinell



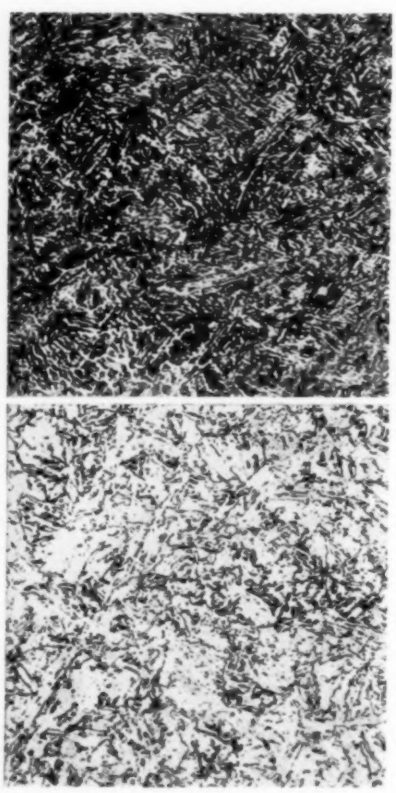


The welding current is slightly lower than that for steel electrodes of equivalent diameter; the electrical characteristics of the arc will vary for different types of coatings, and it is best to arrive at the most suitable amperage by trial. Direct current welding is used in preference to alternating current, and reversed polarity (work negative) is the general rule.

The base metal must be preheated if it is an air hardening or martensitic steel (chromium contents of 4% to 14%), the preheating temperature must be maintained until welding is completed, and the assembly annealed before it cools to normal temperature. High chromium-irons are also preheated. The degree of preheat will vary with the alloy.

Chemistry of Welds — Electrodes of the same analysis as the parent metal should generally be used. Some exceptions follow: In the case of the heat resisting alloys, high in carbon, it is advisable to use an electrode of lower carbon content; less difficulty will then be encountered. If considerable of any of the alloying elements is lost during transfer through the arc, and where this loss is considered harmful, it should be compensated for by using an electrode of higher alloy content or by introducing the required amount of alloy from appropriate chemical compounds introduced into the coating.

If the weld metal cracks in an air hardening alloy, a chromium-nickel electrode, such as 18% chromium, 8% nickel or 25% chromium, 20% nickel alloy will deposit tough weld metal. This may also serve for the welding of the high chromium alloys susceptible to brittleness on welding, such as the 18 to 28% chromium-iron alloys. For important welds, however, this practice should not be permitted; its successful use presupposes (1) that the welded part may be used in the as-welded condition, since the proper annealing heat treatments of the austenitic weld metals and the straight chromium parent metals differ considerably, and a suitable heat treatment for one may ruin the other, or (2) that, if heat treated to place the parent metal in a desirable condition, the inferior corrosion resistance of the weld metal resulting from improper heat treatment is of no importance, and (3) that the service conditions and the design of the welded part will not cause failure on repeated heating and cooling due to stresses set up by the different coefficients of expansion of the two types of alloys.



Hard Martensitic Structure of 5% Cr Weld, as Welded, as Shown on Top, Becomes Spheroidized and Softened After 4 Hours at 1300°F. (200 ×)

The chemical analysis of the deposited weld metal differs from that of the welding rod. Nitrogen is absorbed by the high

chromium alloys, up to 0.28% being found in the weld. Whether high nitrogen is beneficial or otherwise in weld metal has not been definitely established — apparently no great deleterious effect arises and nitrogen may be discounted until further data are available as to its exact action.

Wih an intelligently compounded coating, the loss of chromium may be placed at about 1.0 to 1.5%, which may be considered negligible in the high chromium alloys. Loss of elements possessing high affinity for oxygen may be excessive; approximately 60% of the original titanium content of the electrode and approximately 40% of the columbium content are representative values. Nickel, molybdenum, copper, and tungsten are transferred across the arc without change; this statement also applies to manganese and silicon in normal amounts. Some slight change in composition may occur due to absorption of elements such as manganese and silicon from deoxidizing or arc stabilizing compounds in the covering.

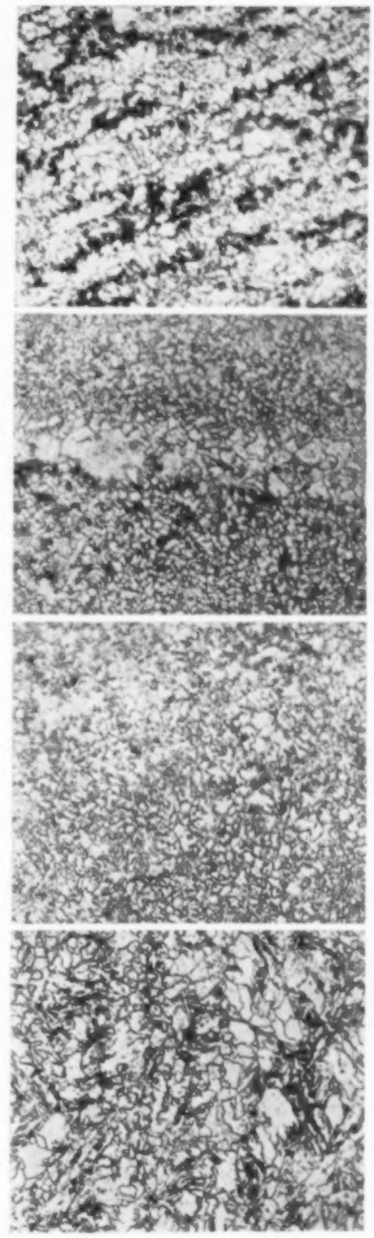
4 to 6% Chromium

A good account of this important alloy has been given only in February's METAL PROGRESS by E. S. Dixon of The Texas Co. He also emphasized the importance of preheating either locally or uniformly, to at least 300° F. (the higher the better). In our operations we maintain the temperature until welding is completed and then place the unit immediately into a hot furnace for heat treatment. In this way cracks in the weld metal, which otherwise would air harden to Brinell 400, may be entirely prevented.

Physical properties of specimens, all weld metal, will vary with the heat treatment as shown in the table. The sketch, which plots the results of hardness surveys, shows that softness may be fully restored by a full anneal at 1550° F. or above, the furnace

5% Cr, 0.5% Mo Weld Metal

Sample	Yield Point	Tensile Strength	Elongation in 2 In.	Reduction of Area	Brinell
(Annealed plate)	33,000	69,000	37.5	77	140 to 150
Weld metal as welded	Specimen cracked				390 to 440
1 hr., 1200° F. } Furnace	106,000	117,000	15.5	42	240 to 270
4 hr., 1300° F. } cooled	70,000	94,000	24.0	55	200 to 230
1 hr. 1500° F. } Controlled	45,000	78,000	31.0	61	160 to 170
1 hr. 1600° F. } cooling	30,000	76,500	31.5	58	145 to 155



Micros at 100 × of Fully Softened Weld in 5% Cr Steel. Weld metal at top, then junction, then affected zone, and unaffected plate at bottom

being controlled so as to cool no faster than 50° F. per hour from above the upper critical point until a temperature of 1200 to 1300° F. is reached, at which the metal may be removed from the furnace and air cooled. Charpy impact of the specimens then reaches 20 to 35 ft-lb. When temperatures lower than the critical point are employed for softening, the properties will depend upon the time held at temperature to permit spheroidization. Where distortion of the welded part must be kept to a minimum during annealing, a low annealing temperature is advisable; four hours at 1300° F. will soften satisfactorily to properties noted in the table.

Metal arc welded joints are being produced to all requirements of the A.S.M.E. Boiler Code for Class I welding. Mr. Dixon in his February article showed bend test specimens — others could be reproduced from a large number of qualification test specimens, each one bent flat with 67% elongation of the outer fibers of the weld metal. This is excellent evidence of the

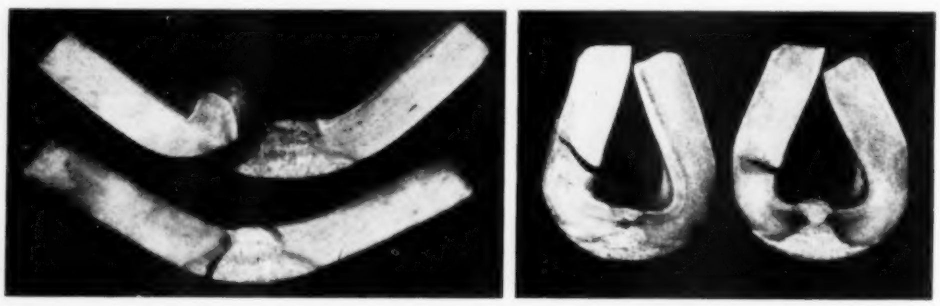
soundness and ductility which may be had with this alloy. The weld also possesses the corrosion and oxidation resistance of the base metal.

Etched macrosections of a multi-pass weld in ¾-in. plate show a thin affected zone at both edges of the V; this is eliminated on annealing.

Weld metal — hard, as welded — and after spheroidizing (softening) at sub-critical temperatures, is shown at 200 diameters magnification in the micros on page 34. A group of four micros at 100 diameters of a single welded joint after full annealing at 1600° F. and controlled cooling are also reproduced, representing unaffected plate, affected zone, junction, and weld.

All of the common commercial alloys in the 11 to 14% chromium range, even the low carbon analyses, are martensitic steels of pronounced air hardening nature; they can be considered as possessing only limited weldability. To successfully weld them by the metal arc welding process requires preheating to a high temperature with heat treatment following immediately after welding. The field of application of the 12% chromium steels might be extended considerably in structures requiring moderate corrosion resistance combined with good strength, provided the carbon content could be lowered in commercial production to a value of possibly 0.04 or 0.05%. Air hardening would then be minimized and heat treatment probably unnecessary.

Conditions as they now exist with a 13% chromium-iron plate, carbon 0.07%, welded with an electrode containing 16% chromium, are shown in the figure at the left. When specimens are tested without heat treatment they break after rather a slight bend through the affected zone alongside the V, which has a Brinell hardness of about 360 as compared with 150 to 170 for the original plate. After such a specimen is annealed at 1450° F. and cooled in the furnace, the hardness of the affected zone is brought down to 180 to 240 Brinell, and fracture on bending and straightening will ordinarily occur in the unaffected plate. The microstructure of weld metal, as deposited, is martensite. Another weld under study analyzed 13.0% chromium, 0.15% carbon; its hardness was 420 to 480 Brinell.



Welds in 13% Chromium Steel Ordinarily Break in Affected Zone; After Heat Treatment the Weld Is Stronger Than the Original Plate

12% and 16% Chromium Steels

The steels in the first category are understood to vary from 11 to 14% chromium, and to carry up to 0.15% max. carbon. They are extremely susceptible to small changes in carbon content in the sense that they are borderline alloys wherein a slight change in analysis will involve an important structural change. As the ratio of chromium to carbon increases the alloy passes from a hardenable steel to one which is more and more insensitive to heat treatments for the carbon remains in solution in the ferrite at all temperatures (hence their name "ferritic alloys," is descriptive).

This must be considered in dealing with their welding characteristics. The influence of additive elements, such as nickel, silicon or titanium, should also be remembered, since small percentages will alter the behavior of the chromium steels when subjected to high temperatures, and hence their welding characteristics. Nickel makes the alloy act more like a steel; silicon and titanium on the other hand promote ferritic microstructure, and a coarse grain that cannot be refined by heat treatment.

Alloys with chromium from 15% to approximately 18% and with carbon below 0.15% represent an extension of the transition zone mentioned above. The pearlitic or martensitic alloys in the lower part of this chromium range are therefore susceptible to heat treatment, and at the same time do not air harden appreciably. For this reason and also because of their high corrosion resistance, this type of stainless iron is extensively used for welded structures by the chemical process industries.

While it is possible to arc weld this group of alloys at normal temperature, preheating (at least locally) to approximately 200° F. is advisa-

ble. As welded the joints are extremely brittle and, where highly stressed in service or subjected to possible impact, should be heat treated by annealing the entire structure at 1450° F. or above, furnace cooling to about 1100° F., followed by air cooling from this temperature. Air cooling from the anneal will also remove brittleness.

As shown in the table alongside, the welded joints in the annealed condition possess satisfactory ductility and impact resistance — although not equal to first class wrought metal in this respect. Toughness at the weld will depend largely on its chromium content, the impact resistance of weld metal reaching low values above 16¼% chromium, as shown in the second part of the table. Hence it is advisable to construct highly stressed, shock resisting parts of alloy with a relatively narrow range of composition, approximately 15 to 16% chromium. If this will not give the desired corrosion resistance, chromium-iron with up to 17.2% chromium may be used as the top limit. The reasons for the low impact values of the high chromium weld metal are associated with the nature of the coarse ferritic grains, incapable of refinement by heat treatment. Three micrographs of a joint in 16% chromium-iron are shown at the left of the group on page 38.

Tensile specimens cut from all weld metal are not greatly affected by chromium content within the range noted at the outset. A representative value for tensile strength of metal, as welded, is 95,000 lb. per sq.in., and 80,000 lb. per sq.in. after annealing. The yield point of annealed weld metal is about 59,000 lb. per sq.in. The corrosion resistance of the welded joints, after annealing, is equal to the parent metal.

Higher Chromium-Irons

Chromium-iron alloys above 18% and with normal carbon contents are entirely ferritic. These single phase alloys in wrought condition are represented largely by two types: 17 to 19% chromium with 0.15% max. carbon and 26 to 30% chromium with 0.30% max. carbon.

They are not responsive to heat treatment, do not air harden and are subject to grain growth at elevated temperatures. The weld metal and the affected zone of the base metal are therefore extremely coarse grained and brittle, as shown by the right-hand group of micros on page 38. The welds cannot be toughened by heat treatment and the alloys in this range may be considered as possessing extremely limited weldability. Brittleness of the welds increases with increasing chromium content, the lower chromium range possessing some slight degree of toughness which permits its use for process equipment under moderately severe working stresses. Welded parts should not be used in services subject to even slight impact loading or under bending stresses. A welded test piece of 28% chromium-iron, tested in bending, broke through the joint with practically zero deflection. At temperatures above 500° F., however, these ferritic alloys become quite ductile; welded structures may be employed at elevated temperatures without danger of cracking in service.

The most important alloys of this group are those generally used for heat resisting purposes.

Charpy Impact of 16 to 18% Chromium-Iron Welds

Chromium in Weld Metal	Effect of Heat Treatment: As Welded	Cooled from 1450°F. in Furnace	Cooled from 1450°F. in Air
17.6%	1.0 ft-lb.	2.7 ft-lb.	15.0 ft-lb.
16.3	1.0	16.5	18.0
15.7	1.0	15.5	21.0

Specimens Below Furnace Cooled from 1450°F.

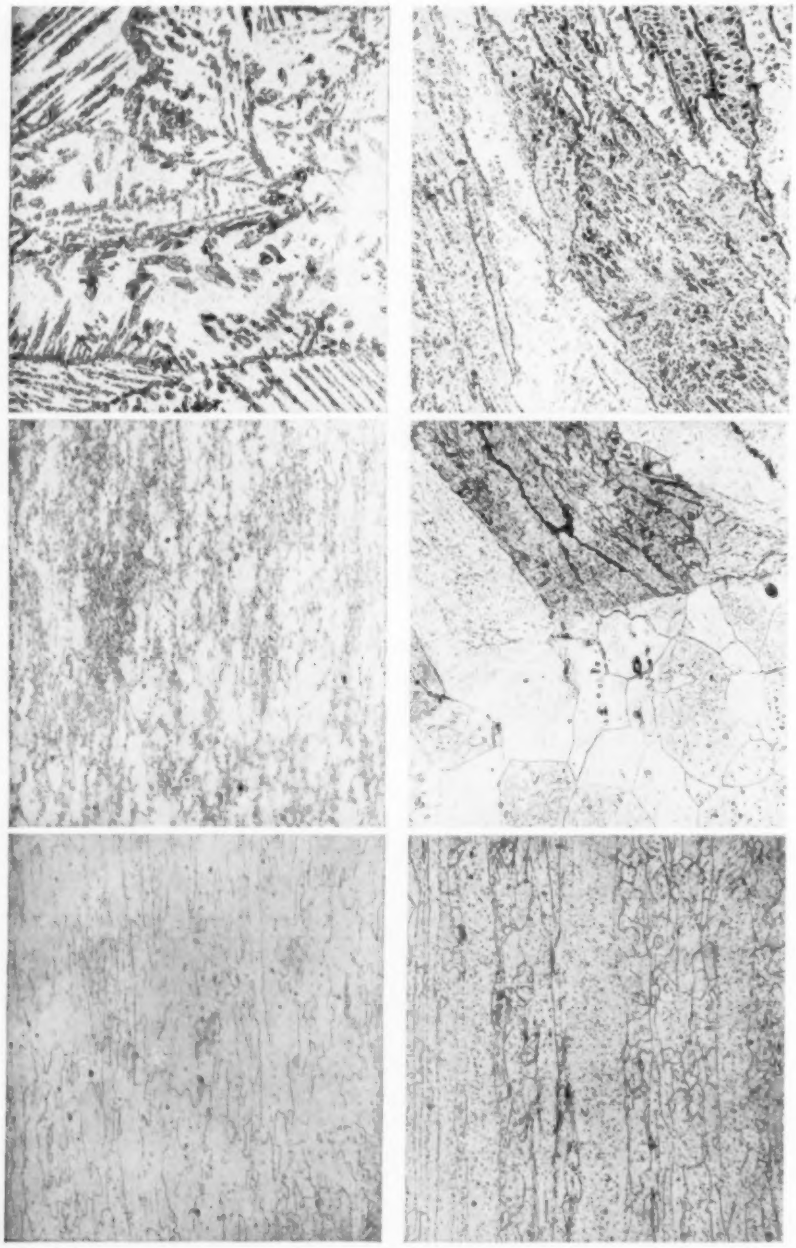
Chromium	Maximum	Minimum	Average
14.1%	26.5 ft-lb.	26.0 ft-lb.	26.2 ft-lb.
15.25	24.7	20.0	22.3
15.75	23.5	15.0	21.0
16.00	19.8	16.5	18.2
16.25	15.5	2.0	13.0
16.50	11.0	2.0	8.0
16.75	15.0	2.0	8.9
17.00	17.0	2.0	5.2
17.0 to 17.5	15.0	1.5	7.3
17.5 to 17.9	6.0	2.0	5.6
18.0 to 18.5	3.0	1.0	2.1

Properties of 28% Chromium-Iron Welds

Material	Carbon	Chromium	Nickel	Nitrogen	Tensile Strength	Elongation	Reduction of Area	Bend Test	Impacts: Notched	Impacts: Unnotched
Plate	0.10	26.0	—	—	75,000	30	60	180	3.0	30.0
Weld A	0.25	28.8	0.56	0.10	53,000	Nil	Nil	Nil	1.0	4.0
Weld B	0.11	27.0	0.21	0.33	66,000	Nil	Nil	Nil	2.5	18.0

having a chromium content of 26 to 30%. In welding such material, preheating is again necessary; residual welding stresses should also be removed by a prompt annealing treatment. Under these conditions sound welds free from cracks may be produced. The table on page 37 shows typical properties of plate and welded joints of this alloy. Weld "B" is one deposited from an electrode with a high nitrogen content to determine whether the grain refining and toughening influence of nitrogen (experienced on castings of high chromium content) would also be prevalent in high chromium weld metal; there was considerable improvement in unnotched impact.

All of the castings of stainless steel alloys may be satisfactorily welded for either the repair of a foundry defect or for joining the casting to another part of either forged or cast material, with the following important provision:



16% Chromium-Iron *28% Chromium-Iron*
Coarse grained weld metal (annealed) at top; affected junction zone at middle; unaffected plate material below

The casting adjacent to the weld must be sound and free from red short cracks, shrinkage cavities, and other porosity; otherwise the contraction stresses set up during the cooling of the weld metal will undoubtedly tear the cast material adjacent to or back from the weld. In pressure castings such a condition will result in endless leakage through the defective zones of the casting, a condition which is practically impossible to check by welding.

Testing of Completed Welds

It is appropriate to call attention to the necessity for making a companion welded test plate as a sample of the work done on any important welded unit of stainless steel. This is necessary in view of the tremendous effect of heat upon the majority of the alloys. Since the base material and welded joints are extremely susceptible, in the majority of cases, to variations in heat treatment, it is necessary to subject the sample to the same heat treatment as the structure. It is best for this purpose that the welded sample be attached or enclosed within the welded unit during its heat treatment.

It is also appropriate to call attention to the availability of X-ray examination for welded joints in these special steels. For important parts such as stainless steel pressure vessels one should demand a complete X-ray examination of the welded joints, since the surface appearance does not disclose the presence of a blowhole some distance within the weld, which after some period of operation in service might open the way for leakage. This has happened by reason of the presence of a single blowhole.

If such leakage should develop in service, repair by welding would be necessary, and since the repair weld might ruin the adequacy of the part repaired with respect to its corrosion resistance, heat treatment would then be required, and this might be impossible unless the structure were dismantled and returned to the builder.

On the other hand, since the majority of stainless steel constructions involve comparatively light thicknesses, where adequate procedure control followed by a thorough surface inspection practically assures sound weld metal throughout the thickness, X-ray examination may be considered unnecessary. Considerable personal judgment must be used in deciding this question. Certainly for high temperature, high pressure equipment in chemical processing, the cost of X-ray examination is justifiable.

Duralumin in Aircraft Construction

By F. P. LAUDAN
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ALL-METAL CONSTRUCTION FOR AIRcraft, a gradual development from the wood and fabric type used during and immediately after the War, has brought with it changes in aircraft manufacturing methods as radical as the changes in the industry's products themselves. Where spruce and cotton once were the order, strong but light aluminum alloys now hold sway. Activities of certain factory branches have diminished; those of others have grown. Chisels, planes and hammers have been replaced, to a large extent, by presses, by riveting guns and metal drills. New and ingenious metal working processes have been adopted.

No place could afford a better field for study of these changes than the plant of Boeing Aircraft Co., Seattle, Wash., one of the leading producers of military and commercial aircraft. Here the whole story has been unfolded as one type of construction has given way to another, starting with the "stick and wire" type of 1916 and culminating in the all-metal type of 1935.

What this trend has meant to the progress of aircraft design and construction may best be gathered by looking at the first and latest planes made by this organization. The original Boeing was a seaplane trainer of the wood and fabric type, equipped with a 120-hp. engine. With a gross weight of 2600 lb., it boasted a cruising speed of around 60 miles an hour. External struts and wires did not aid its speed.

Contrast with this the latest commercial plane, an all-metal, low-wing, 200-mile-an-hour transport, 75 of which have been produced for air lines both in this country and abroad. Equipped with two 550-hp. geared and supercharged Wasp engines, as well as with three-bladed controllable pitch propellers, this plane has a gross weight of 13,650 lb., can climb as high as 11,500 ft. on either one of its two engines, and has a top speed of 200 miles an hour with a full load of ten passengers, two pilots, stewardess, baggage and cargo. Not an outside strut or wire reduces the speed. With all-metal construction has come the cantilever type of wing and tail surfaces, internal bracing, and neat fairing to eliminate parasitic drag. The landing gear is retractable, permitting a differential of 20 miles an hour in the plane's speed.

More than 60 of these carriers (type 247-D) now are in the service of United Air Lines, placing the two oceans as near together in traveller's time as New York and Chicago on the fastest railroad train. Still further reductions in travel time now are being planned, to provide overnight movement of passengers, mail and express between points as distant at 2300 miles.

One of these Boeing 247-D commercial transports, standard in all respects, earned laurels when, with Col. Roscoe Turner and Clyde Pangborn at the controls, it took second place in the speed event of the London to Melbourne air race, although vying with some of the finest racing planes, especially built. In this event, as well as in recent speed flights in the United States, American transport planes have won new international recognition which has quickly been reflected in orders from abroad.

Latest in the Boeing military aircraft line are diminutive all-metal pursuit planes for the Army Air Corps (type P-26A) ranked as the fastest air-cooled fighters in the world. Equipped with a 550-hp. Wasp engine, the P-26A is particularly designed for speed and maneuverability in combat at high altitude. In speed, these little single-seater fighters are, of course, faster than the big air liners since they are designed to carry

no more than a pilot, two machine guns and a small quantity of bombs.

Boeing commercial and military planes are of the same all-metal, semi-monocoque type of construction. The 247-D transports have a wing span of 74 ft., while the span of the P-26A pursuit is slightly under 28 ft. An article in METAL PROGRESS, July, 1933, contained some pictures which illustrate the trussed wings and the skeleton of the fuselage. All models are sectionalized and constructed in rigid jigs so as to be interchangeable with another from store or a grounded plane in case of damage. Obviously this is a point of extreme importance in mass production and continuous operation.

Fabrication of Duralumin

The well known strong aluminum alloy popularly known as duralumin (or "dural") is the metal chiefly employed in both military and commercial planes, being used for longerons, skin stiffeners, bulkheads and skin covering. In addition many smaller parts are made of it. Skin covering ranges from 0.013 to 0.051 in. in thickness, depending on its location and the loads it is required to carry. Metal in the longerons ranges in thickness from 0.051 to 0.091 in. Outboard spar chords of the transport plane are of 0.316-in. duralumin. In bulkheads, duralumin as thin as 0.025 and steel as thick as 0.500 in. is used. Chromium-molybdenum steel tubing for the inboard wing spar chords of the transport have walls 0.156 to 0.172 in. thick.

After leaving the receiving store, the duralumin sheet or strip goes to the primary shop where it is cut to size. It then is routed via heat treatment shop either to the hammer shop for forming or to the sheet metal shop.

Tensile strength of the metal is more than doubled in the "dural heat treat." Equipment here consists of two long salt baths, internally fired by gas; a cold water tank and a hot water rinse tank. The salt baths contain a molten solution of sodium and potassium nitrate in equal parts, kept at a temperature of 950° F.

The metal is left in the baths for from 12 to 22 min., depending on its thickness. It then is dashed into cold water and run through the hot water rinsing tank. Approximately 78 hr. are required at room temperatures for the metal to age to its full strength, after which it is Rockwell tested to make certain that it comes up to the required specification.

By means of such heat treating methods, tensile strength of duralumin is increased from 26,000 as received to 55,000 psi. In the latter condition its yield point is 32,000 psi. with elongation varying according to the thickness of the material, from 10 to 18%. Hardness specifications vary from Rockwell 78 (using ¼-in. ball and 100 kg. load) for 0.024 in. thick and under, to Rockwell B-60 for 0.065 in. or over.

Where warping is a major problem, forming

Heat Treatment Plant For Duralumin Aircraft Parts Consists of Long Tanks With Molten Salts at 950° F., Cold Water Quench and Hot Water Wash. Strength is more than doubled

is done during the aging period, after heat treatment. Otherwise the matter of forming before or after heat treatment is largely a question of convenience.

Large and thin gage parts for the plane are formed, after heat treatment, on a 700-ton hydraulic press in wood and steel dies; dural ranging in thickness from 0.013 to 0.125 in. has been handled. Sheet for such parts as cowl segments, fairing and exhaust systems goes to the drop hammer shop to be formed in lead and zinc dies made from molds.

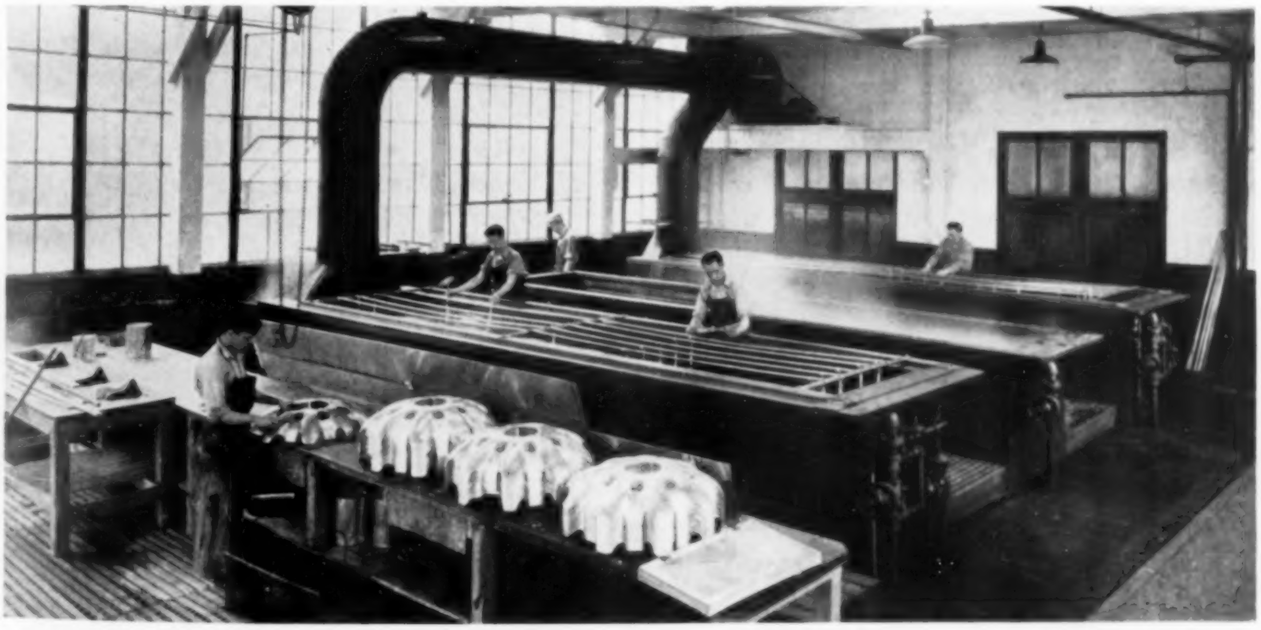
Where considerable lengths of the same section of stock are required, a draw bench is used. Flat sheet, drawn by a moving carriage on an endless chain and passing through two sets of dies held in a vise, is formed into virtually any shape of channel section desired. Tubing is similarly formed into square, rectangular, oval or streamlined shapes. Sheet metal from 0.016 to 0.091 in. and tubing from 0.035 to 0.250 in. wall thickness have been handled on the draw bench.

After heat treatment duralumin goes to the finishing shop, to be anodically treated for protection against oxidation, or to receive a primer coat, or both. In the case of the transport, Duco F6199 is used as primer, while Berryloid red iron oxide primer is employed for the P-26A pursuit planes. The anodic process protects duralumin parts from corrosion. The treatment may be pictured as the reverse of electro-plating, in that it partially etches the surface and produces a thin oxide film which will resist salt water and any moist air condition.

Parts to be treated are suspended in a 3% chromic acid solution. Current from a special generator, passing through the metal and the solution, is stepped up from zero to 40 volts at the rate of 5 volts increase per minute and is held at 40 volts for a period of 30 min. Amperage varies with the surface area of the metal in the bath.

The Boeing company first used the anodic process merely for the duralumin parts going into Navy planes. So successful did it prove, however, that it later was adopted for duralumin and aluminum parts for all planes. The outer skin of the new transport is left in the state as it emerges from the anodic process without use of other exterior finish, thus permitting a saving in the weight of paint — a considerable item. The color is called "anodic grey" — closely resembling a light battleship grey.

In the further fabrication fixtures and jigs of every description are employed to insure the utmost accuracy and interchangeability. Parts for bulkheads, for instance, are assembled, drilled and riveted in wood jigs having metal-lined drill holes, all accurately located. Light gage duralumin channel sections used for skin stiffeners are assembled and drilled in wood cradle jigs. In this way, as many as 150 parts can be brought together into a single unit, and this unit then assembled into the plane. For all new large projects, months of tooling precede produc-



All Duralumin and Aluminum Is Put Through the Anodic Process to Protect it From Corrosion. A 3% chromic acid solution is used; current from a generator passes through the solution, oxidizing everything immersed

tion. The wood shop, which once built virtually the entire plane, now has a major hand in this type of work.

No welded duralumin now enters structural parts, for the reason that the metal depends on heat treatment for strength and any subsequent application of heat changes these qualities in the heated zone. Certain small, non stressed items are welded. The art of electric spot welding is being given attention throughout the aluminum industry but thus far has not been applied by us to structural items.

In the matter of fabrication, we have assigned certain divisions of the plane to certain shops. Thus, the "control surface shop" occupies itself with rudders, ailerons, fins, elevators and stabilizers; the "wing shop" — which, incidentally, once dealt entirely with wood and fabric — busies itself in assembling the metal wings of 1935 planes; the "body shop" handles all body assemblies. Altogether, there are thirteen shops in the plant — each engaged in its particular line of work.

Parts coming from the various shops go to an assembly bay where planes take final form. Transports consist of rear body sections, nose sections and center sections, motors, landing gear, and wings. After cable work is completed and interior details cared for, the plane is inspected and is ready to take the air.

Other Strong Metals Used

This article has dealt primarily with the use of duralumin and methods of its fabrication. The impression should not be gained, however, that other metals are not used in the production. Chromium-molybdenum seamless steel tubing is used for the transport's landing gear, engine mount, tail wheel and inboard spars; un-alloyed aluminum for fuel tanks; stainless steel for exhaust stacks as well as for ball and roller bearings; bronze for some bushings; steel or bronze for gears, pinions and worm drives used in the landing gear, tail wheel and controls.

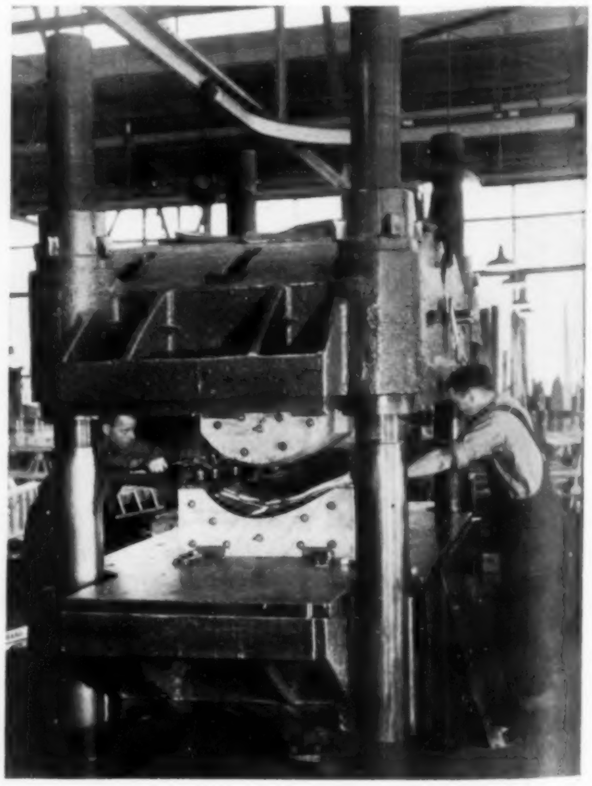
A separate heat treating room is provided as a division of the machine shop. Equipment consists of three large pot furnaces, gas heated, and three electric furnaces for the larger parts, as well as a number of pot furnaces for smaller steel tools and parts.

Steel parts, as differentiated from assemblies, go to the heat treating room. Chromium-molybdenum steel, S.A.E. 4130, such as used for landing gear parts and spar chords, may be raised, from a normal tensile strength of 90,000 psi. to 180,000 psi, with a yield point of 150,000 psi. and 8% elongation. Nickel steel, S.A.E. 2330, such as employed for terminals, bolts and trunions as well as for certain forgings, is raised from a tensile strength of 85,000 to as high as 200,000 psi. with a yield point of 155,000 psi. and elongation of between 11 and 12%.

Whereas the anodic process is used for dural, the cadmium or chromium plating process generally applies for all low alloy steel parts going into aircraft, for its protection against corrosion.

So much for all-metal construction, as practiced at an outstanding aircraft plant. As has been indicated, this type of work did not come overnight. In the case of the Boeing company, the welded steel tube structure marked the first use of metal. Then, in the order named, came a combination of welded steel tubing and bolted duralumin tubing, complete bolted or riveted dural tubing and, at last, the metal monocoque type of construction, with all-metal structures and all-metal wings.

Changes in manufacturing methods went hand in hand with these changes in types of construction until today the plant is scarcely recognizable as the same institution which was the home of wood and fabric planes a few years ago.



Many Sheet Duralumin Parts for Skin and Fairing Are Pressed in Dies Made of Hardwood

Quenching in Water, Brine & Oil

By I. N. ZAVARINE
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Massachusetts Institute of Technology
Cambridge, Mass.

A HOT PIECE OF METAL IS TAKEN OUT of the furnace and plunged into a liquid bath; this operation is called "quenching." The ultimate object of the operation is the modification of the physical characteristics of the metal in the desired direction. Certain metals are hardened by quenching; others are softened.

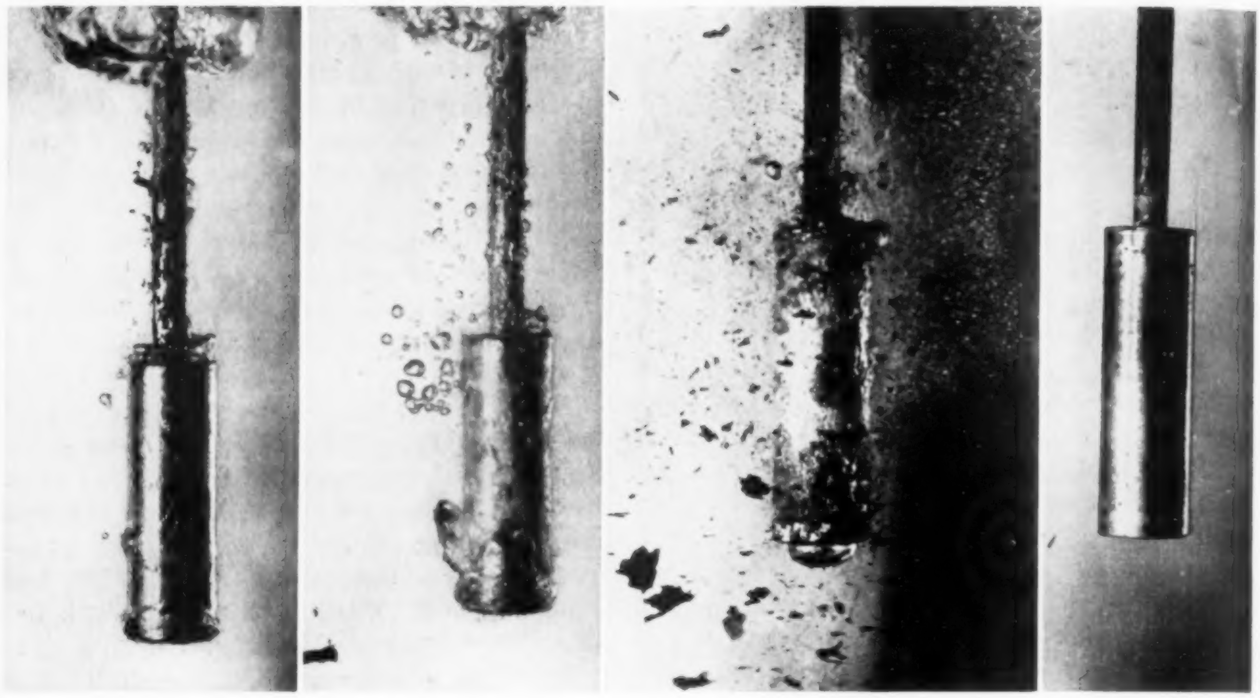
Quenching of metal involves the transfer of heat from the piece of metal to the quenching bath. The point of departure from which the heat starts its travel and the point of its ultimate destination are quite clearly defined by the conditions of the operation; the mode of heat travel is quite uncertain. Heat, being invisible and imponderable, must be studied by its reactions.

The flow of heat from and through the piece of quenched metal is studied by observing the temperature. Years of hard effort and reasoning were required to introduce the conception of the "rate of heat flow from the quenched piece of metal to the quenching bath." Once the conception of the rate of cooling of the metal in the quenching bath was firmly established and the effect of the rate of cooling upon the physical properties of quenched metal properly studied, the fruitful sequence of these ideas was the classification of the quenching liquids with respect to their capacity to cool the metals at different rates and the elimination of non-essential quenching mediums.

(It should be recalled here parenthetically that the ancients believed the mysterious changes in physical properties of the quenched metal were not due to the loss of heat, but to the acquisition of ingredients from the bath; hence the complexity of the ancient recipes for the quenching baths. These ideas were not dead in 1896 when Metcalf wrote his manual on "Steel," for he vigorously condemns the humbugs that claim to make ordinary steel into a tool steel by quenching it in some greasy mess.)

The behavior of the metal in the quenching bath has received considerable attention from numerous investigators. One of the best statements of the case is H. J. French's book, "The Quenching of Steels," published by the American Society for Metals. The knowledge of the rate of cooling, of the effect of the rate of cooling upon the physical properties of the metal, and of the existence of the temperature gradients in the quenched metal, gives extremely useful conceptions in every-day heat treating practice. Most recent study has been on the changes which occur when hot steel is quenched to certain elevated temperatures and held there for a considerable time before cooling further to room.

The behavior of the liquid medium during quenching has received considerably less attention than these matters. The knowledge that certain quenching mediums cool the metal faster than others is considered quite sufficient in many practical cases, but the existence of the difference between the quenching media, with respect to their capacity to cool the metal at different rates, troubles the inquisitive mind. Consequently some photographic studies of the behavior of a few quenching mediums are offered here with the hope that they may help to visualize the conditions existing in the bath during quenching. The studies were not pursued to the ultimate end and no final conclusions are here offered other than an explanation of the superior quenching speed of brine solutions. The limitations of the photo-



Instantaneous Views of Cylinder in Water Quench. At beginning a relatively quiet film of steam surrounds the specimen, which increases gradually in turbulence; two seconds later the action is violent enough to tear off scale, but in five seconds quenching is complete

graphic attack of the problem are quite obvious.

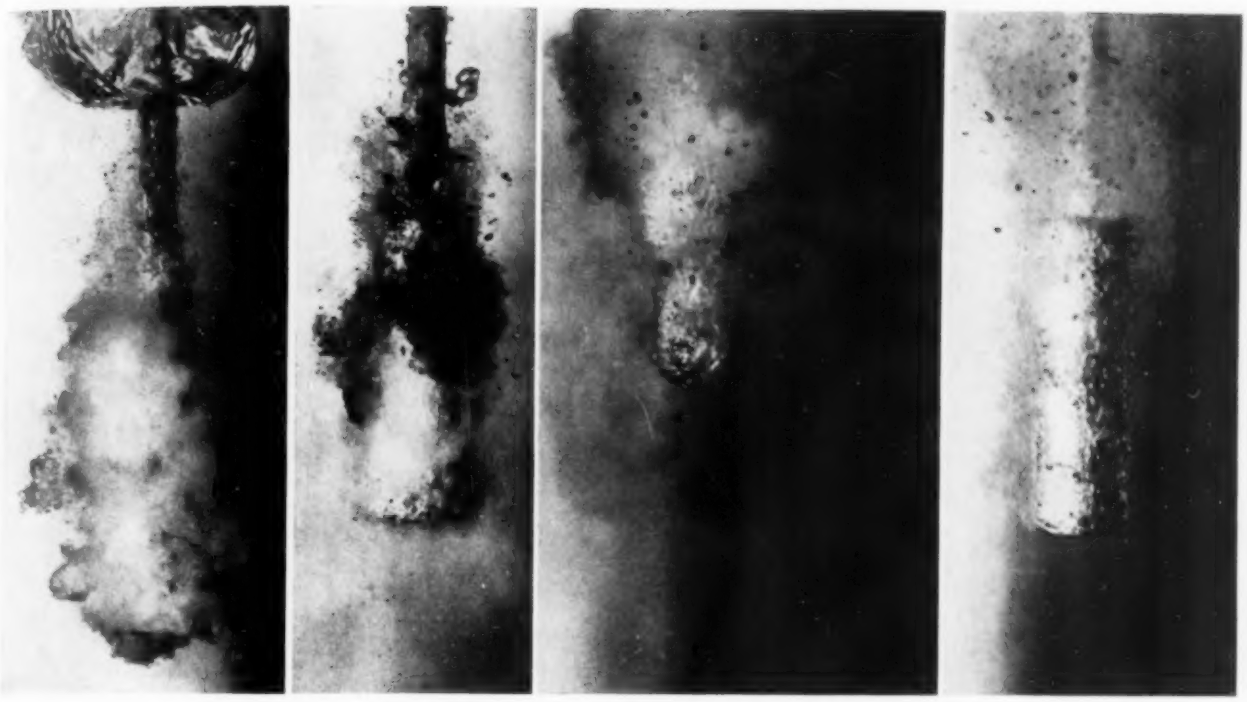
The photographs appearing with this article were made by a method of high speed photography developed by Professors Egerton and Germeshausen at the Massachusetts Institute of Technology. It consists of instantaneous illumination of the object by means of a spark of high intensity. The spark is produced by a discharge of an electrical condenser between two magnesium electrodes; the duration of the spark is estimated to be of the order of one millionth of a second, short enough to stop effectively all motion of the object being photographed.

Timing of the exposure is accomplished by a separate electrical circuit which acts as a trigger to set off the condenser; the accuracy of timing depends on the perfection of the mechanical devices that close the trigger circuit. The intensity of light, notwithstanding the shortness of the exposure, is so great that the pictures were taken on the ordinary photographic film through a layer of water or oil a few inches thick. The study of the quenching mediums by means of photography must be confined through necessity to transparent liquids.

The procedure in making the pictures was briefly as follows: a specimen ⅝ in. diameter and 2 in. long, supported by a ¼-in. rod, was heated in a vertical electric furnace located above the quenching bath. Preliminary to heating, a photographic camera was focused on the submerged specimen, to reproduce about full size. When properly heated, the specimen was dropped into a square-sided glass jar containing the quenching medium. Suitable guides were used to insure a proper alignment of the specimen in the field covered by the photographic camera. The trigger circuit was closed by a device connected with the supporting rod at times when a freely falling specimen was photographed. A more elaborate timing device was required for obtaining delayed quench or two-step quench pictures.

Water Quench

The beginning of water quenching is characterized by the formation of a thin film of steam around the hot specimen. This film is by no means stationary, but varies in thickness from instant to instant in a sort of wave motion. The waves are shown by wrinkles of the film of steam shown in the first two views of the first group. A balloon of air, dragged into the water by the falling specimen, is seen rising upward. When quenching is studied with a high speed motion picture camera, the waves are seen moving in an upward direction. Water quenching is surpris-



In a Brine or Caustic Solution the Action Is Quite Distinctive. A cloud of salt crystals is thrown away from the hot metal with explosive violence. In the third view the sample is dropping rapidly out of this cloud, and in the last the quench nears completion

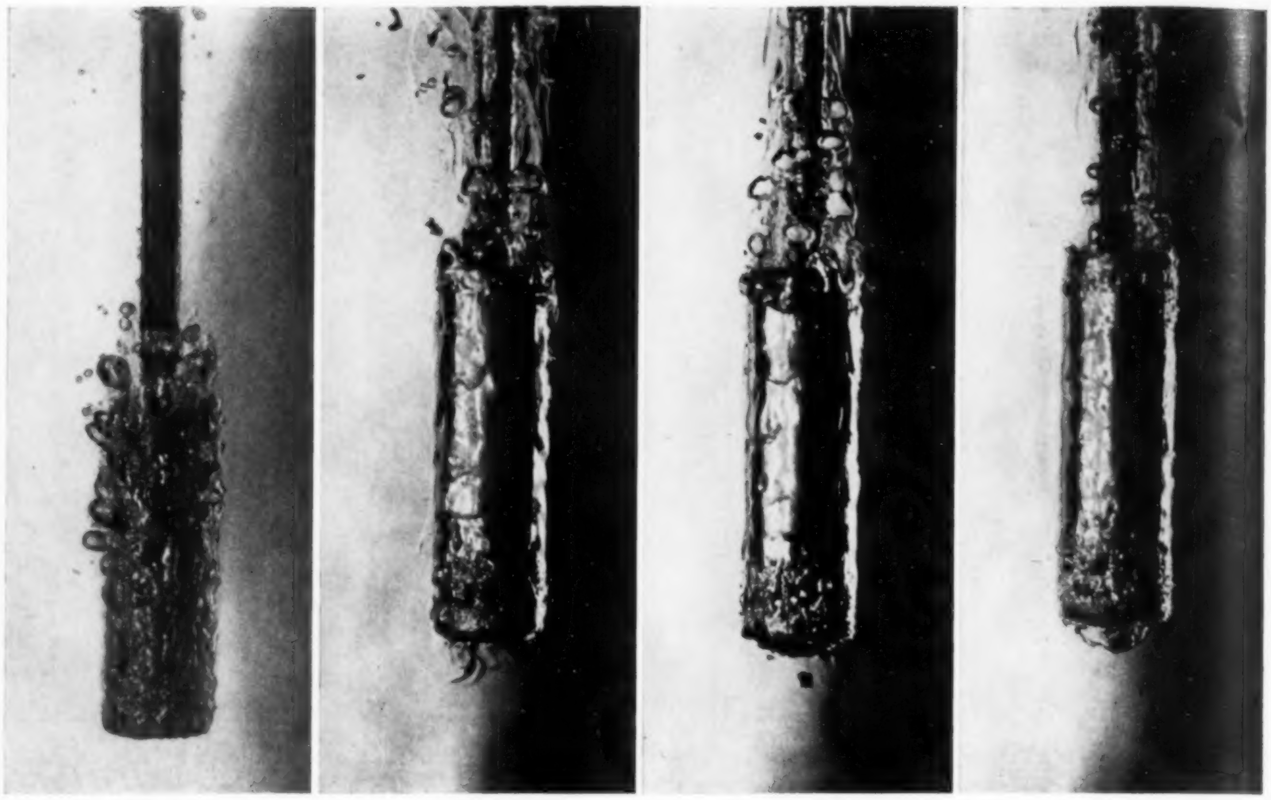
ingly quiet at the start; much more action is shown towards the end of the quenching operation. The third view in the first set, taken two seconds after the beginning of the quench, shows that the water is now hot around the specimen; a few bubbles of steam can be seen on the surface of the specimen, also a large bubble entrapped at the bottom of the specimen. The last view is taken several seconds later when quenching is complete, and is given to show the contrast with others in this article.

Quenching in Brine

The beginning of a brine quench is shown at the left of the second group. These two pictures were taken at the instant when a freely falling specimen was coming to rest in front of the camera. The brine has just touched the hot surface of the specimen and a cloud is instantaneously formed, fragments of scale are flying away, but there is no question that the main cloud consists of crystals of salt.

The phenomenon can be described as follows: The instant the brine touches the hot surface of the specimen, water evaporates, crystals of salt are left behind, deposited on the surface but are instaneously blown off with an explosive force. The process repeats itself as quenching proceeds; the cloud grows larger and larger, obstructing the view of the specimen until the very end of the quenching operation. Then the cloud is raised by convection currents, salt is redissolved and the cold specimen is exposed to view. A very unfortunate occurrence from the point of view of photography!

It was necessary to resort to the following procedure to obtain a glimpse of the specimen behind the salt cloud. The specimen was quenched in brine, retained for a desired period of time in a position somewhat above the field covered by the camera, then allowed to drop to a lower position now in the field of the camera, and photographed. The results of such two-step quenching are shown in the right pair of the second set. In one the specimen is seen coming out of the salt cloud which was allowed to form by retaining the specimen for an instant in the upper position. Only the lower end of the specimen is clearly seen, and it is covered by numerous steam bubbles which indicate a violent agitation taking place in the quenching medium near the surface of the specimen. The other shows similar conditions $\frac{1}{4}$ sec. after the beginning of the quench. Concentration of the brine affects only the density of the salt cloud, the rest of the conditions remaining apparently without appreciable change.



Oil Quenching Acts Like Water Quenching at a More Deliberate Pace. Bubbles of oil vapor form quickly, but the vapor quickly forms a relatively thin layer. Note bubble of vapor trapped at bottom in last view, taken after 5 sec. quench

Caustic soda quench shows conditions quite similar to those of salt brine.

Oil Quench

Transformer oil and "Russian oil" were also used as quenching media. The beginning of the quench in transformer oil is shown in the last set of views, wherein the wavy film of oil vapor and numerous bubbles filled with vapor can be clearly seen. Later stages of the oil quench are also shown; Russian oil was used in these quenchings because of its transparency. Intervals of time from the beginning of the quench are ½, 1 and 2 sec., respectively. The film of oil vapor around the specimen and the rising bubbles of oil vapor are again plainly seen; the wrinkles indicate a wavy motion of the film. The last one also shows a well formed bubble of oil vapor entrapped at the bottom of the specimen.

Conclusions

Photographic records of the behavior of the quenching mediums presented here lead to the following observations:

Water and oil behave during quenching somewhat similarly with respect to the formation of continuous envelopes of steam or of oil vapor around the quenched pieces. In both cases the envelopes are in a continuous state of motion during quenching, the film growing in thickness and collapsing from instant to instant in a sort of wave motion. The water film appears to be thinner and in faster motion than the oil vapor film, probably due to the condensation of steam and lower viscosity of water.

The behavior of the brine or caustic soda solution is quite different from that of water or oil. The instant the salt solution comes in contact with the hot metal, a steam film is formed, accompanied by precipitation of salt on the surface of the metal which, in turn, leads to a violent explosion of the salt crystals. The film of steam surrounding the metal is continuously ripped off by this bombardment by the salt crystals. The flying crystals prevent the formation of a continuous film of steam and lead to violent agitation of the solution in the vicinity of the quenched metal. Obviously, the greater velocity of brine or of caustic soda quench, as compared with water quench, is due principally to the mechanical agitation of the quenching solution induced by the exploding salt crystals.

Metals Used in the Oil Industry

A SERIES OF PAPERS ON THIS GENERAL topic occupied an entire day at the recent meeting of the American Institute of Mining and Metallurgical Engineers in New York. How important this is may be judged from the fact that the oil and gas industry absorbs about 8% of the total steel production, and of this a big share is buried in the ground as pipe lines or oil-well casings, or installed in refineries and subjected to various kinds of corrosive liquids and hot gases. Hence the total amount of loss due to deterioration is enormous.

Service at Sub-Zero Temperature

To the many difficult requirements formerly imposed upon steel by the petroleum industry now comes pressure vessels for dewaxing purposes, operating down to -75° F., and even lower. High grade carbon steel plate, suitable for boiler work, loses most of its toughness (as measured by impact test) before reaching such low temperatures. According to R. K. Hopkins, director of metallurgical research of M. W. Kellogg Co., in a paper on "Welded Pressure Vessels," there is some indication that a fine grained carbon steel may be tough at sub-zero temperatures, if thick plates can be made with fine grain.

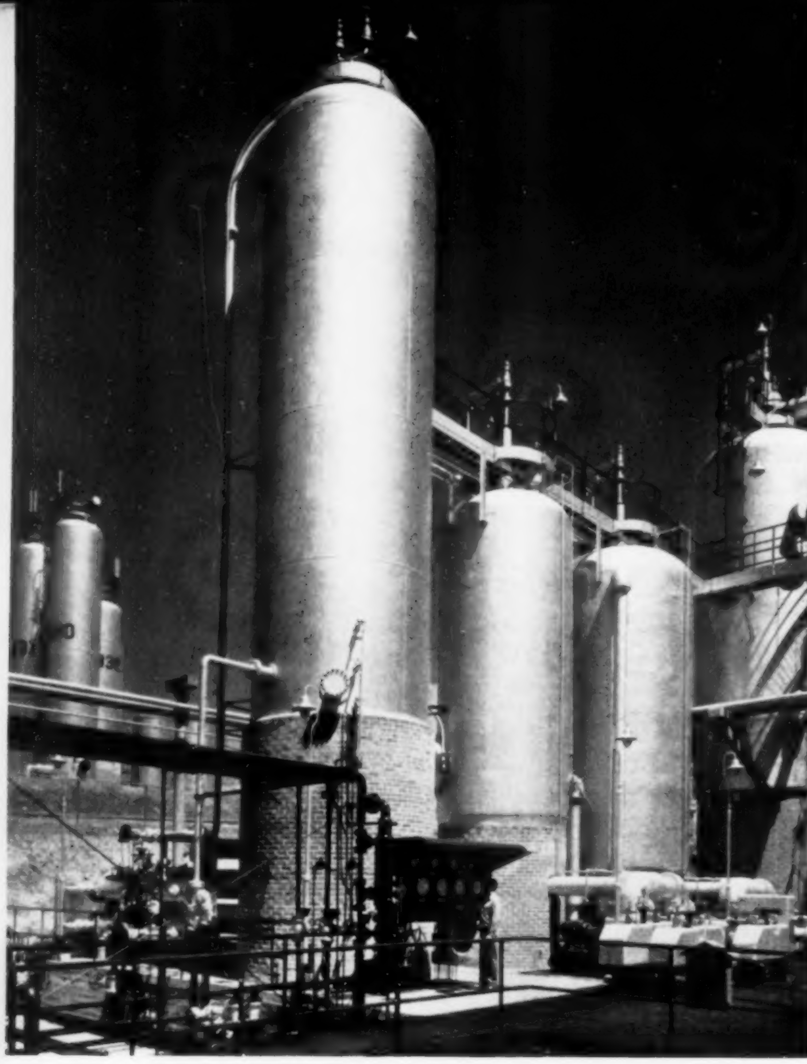
For that reason alloy steel is indicated, and a number of welded vessels up to 11 ft. diameter, 1¼ in. wall thickness have been made by the Kellogg company of low carbon, 2¼% nickel steel. Nickel is an alloy of long and honorable history; steel companies are thoroughly familiar with the melting and rolling of low nickel steels; they are simple to fabricate and weld; apparently the only drawback is the extra cost for the nickel, — but how can you get something for nothing?

Numerous investigators have established the fact that the S.A.E. nickel steels are intermediate between ordinary carbon steels which are quite brittle at arctic temperatures, and the austenitic steels (like 18% chromium 8% nickel) which retain their high toughness unimpaired. The commercial problem therefore was to find a proper balance of nickel, carbon and manganese in a steel for requisite properties at -75° F. Tests made at Battelle Memorial Institute indicated that metal from a heat containing 2¼% nickel with 0.15% carbon and 0.50% manganese was considerably tougher than another with all these elements substantially higher, and was less sensitive to variations in temperatures of the last pass in the rolling mill, and of normalizing and strain relieving operations. In all these tests Charpy impact at 75° F. varied from 41 to 50 ft-lb.; at -75° F. the limits were 32 and 47 ft-lb.

Mr. Hopkins indicated that there is no difficulty in welding the 2¼% nickel steels so that the joints pass the tests required by the Boiler Code for Class I vessels (which are practically the same as the American Petroleum Institute's Code) of which the most drastic is the requirement of a free bend with minimum elongation of 30% on the outer fiber of the welded joint.

Such studies were made on specimens cut from the fusion zone in welds (weld metal approximately equal to base metal in chemical composition), from the transition zone, from the metal heated by the welding operation and from the unaffected plate. Such specimens after heating to 1150° F. (the usual stress relieving temperature) show good toughness at both 75° F. and -75° F. If air cooled from 1900° F. (as would be done to a dished or flanged plate) and then stress relieved, the impact at +75° F. was improved but at −75° was quite low, especially in material on the high side in nickel, carbon and manganese. Hence the desirability of normalizing at 1525 all plates heated in fabrication, and then stress relieving the completed vessel; this restores — and even betters — the toughness at −75° F.

Some tests on completed vessels were described by the author. They were filled with gasoline at 250 lb. pressure, refrigerated 12 hr. to



General View of Type of Equipment Installed for Taking Asphalt and Waxes Out of Lubricating Oil by Mixing With Propane and Refrigerating to —45° F. Photographs on these two pages courtesy Union Oil Co. and National Petroleum News

—50° F., and then hammered vigorously while cold and under pressure. No troubles have been encountered with these vessels in service.

Heat Resisting Castings

Contrast this sub-zero service with that required of metal in so-called cracking stills, wherein the yield of gasoline from crude oil is increased by subjecting it to high temperature and pressure. In design the equipment is related to a tubular boiler. Beams, tube supports, hangers and other fittings for such stills must withstand considerable load for extended campaigns, bathed in hot furnace gases. Temperatures are not precisely known, but according to W. F. Furman of Duraloy Co., Pittsburgh, they probably seldom exceed 1600° F. (Fortunately they are fairly constant.) Such represents the principal use of heat-resisting castings in the petroleum industry, and this occupied the most of Mr. Furman's contribution to the symposium.

While many alloy compositions have been used (and failures have been comparatively rare) three types have received most favor. For operating temperatures ranging from 1600 to 1800° F., Mr. Furman recommends the 25% chromium, 12% nickel analysis, although if high sulphur fuel is burned 29% chromium, 9% nickel would be preferable. These would include the conditions in service most frequently met. For higher temperatures, occasionally met, where sulphurous gases are not feared, the 35% nickel, 15% chromium type would have added strength and toughness from its increased nickel. For the lower temperature ranges, the 18% chromium, 8% nickel steel would be suitable. Oxidation is not a serious factor if chromium is 24% or over.

Design of furnace parts which must carry loads continuously without sag even when quite hot, is difficult. Creep tests have been devised to discover the safe loads, but Mr. Furman would rather rely upon figures derived from successful operation. He points out that the creep values change rapidly with temperature and the laboratory work is liable to introduce large percentages of error. Test results are extrapolated from runs only a fraction of the expected useful life, yet it is believed that in some instances slow changes are going forward in the hot alloy. Likewise test samples are always of higher average quality than completed castings, and no allowance is made for deterioration by oxidizing, sulphidizing or carburizing gases met in service.

The accompanying table has been assembled from four important alloy foundries, and represents their appraisal of unit loads on successful installations. Mr. Furman believes that the average is nearly right for long service in furnace settings of petroleum stills.

Safe Loads for 25% Cr, 12% Ni Castings

Observer	1500°F.	1600°F.	1800°F.	2000°F.
A	2750 psi.	1700 psi.	500 psi.	125 psi.
B	970	660	250	90
C	3000	1700	800	100
D	3000	1700	350	100
Average	2500	1500	500	100

He also gave some interesting thoughts as to the content of other chemical elements in heat resisting castings of the 25-12 type. In a discussion of carbon content, he emphasized that the casting must first of all be sound; soundness is more to be desired than any theoretical composition, if the latter cannot produce sound castings. He advocated a carbon content of 0.30 to 0.40% (0.50% is favored as the top limit by others), although even higher carbon contents are easier to

cast and stronger in laboratory tests. He gave some instances from practice to prove his contention that higher carbon alloys grow brittle in long service, and noted that the definite trend in alloy foundry practice is toward lower carbons, even though no premium is generally charged.

For high temperature service, an alloy should be chosen which has a stable microstructure. Here again is a reason for limiting the carbon content, else the solid solution (austenite) transforms and precipitates carbides. This, in Mr. Furman's opinion, is even more likely to happen to castings with carbon on the high side during service around 1500° F. than it is in the higher temperature ranges. Titanium is useful as a stabilizer against such changes.

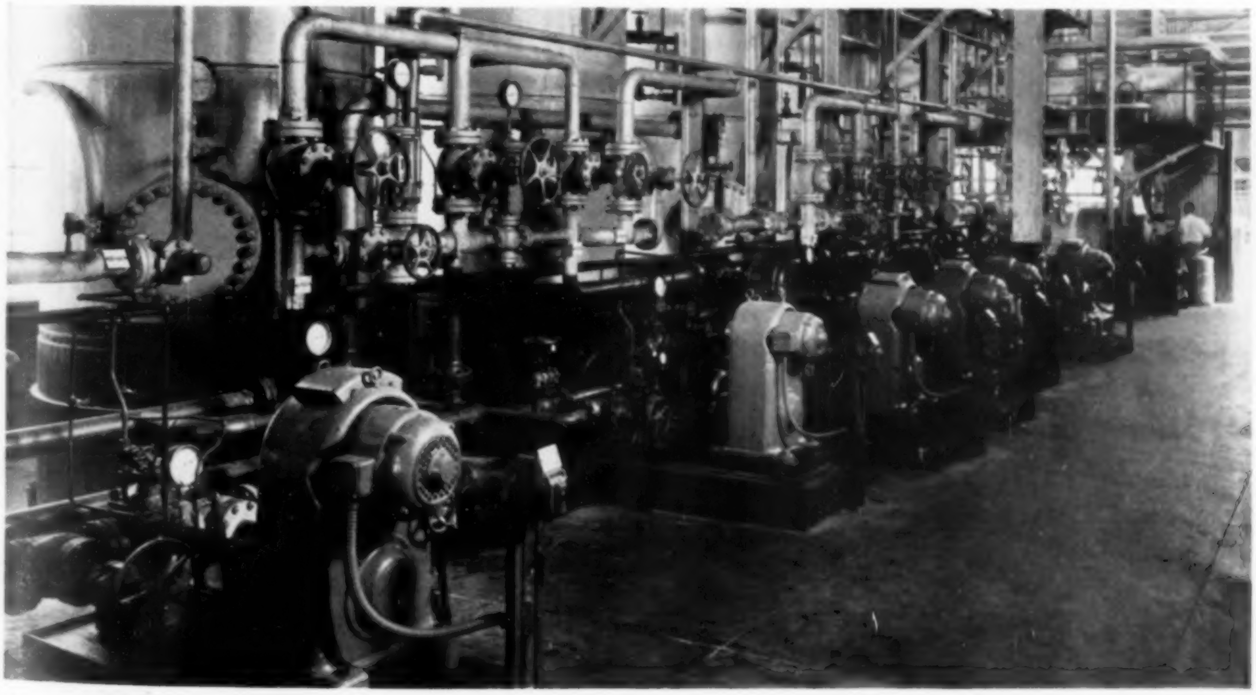
Tungsten has been added to 25-12 alloys as a strengthener. While 2 to 4% does have this effect on laboratory tests, he is doubtful whether it continues for a long time at 1600° F. and hotter. The same may be said for molybdenum (although the latter has undoubted advantage to resist corrosion by liquids).

Liquid Corrosion

A companion paper to the above discussed corrosion of metals in various refinery services and was read by J. E. Pollock, E. Camp and W. R. Hicks of Humble Oil & Refining Co., Baytown, Texas. It gave results on over 200 commercial metals and alloys in 25 different test conditions. The American Petroleum Institute test procedure was used, as specified in the 1930 code for determining the resistance to corrosion of metal samples in petroleum refining processes, and involves the exposure of cleaned and weighed samples to the liquid at certain critical points in the process, including in the materials samples of metal of known life in the given conditions. The services were chosen because of the amount of material involved in such service, or because of the severity as judged by the replacements necessary in the equipment.

The results, of course, represent a tabulation of great size which merits the study of every one with a close interest in refinery problems. Only some general conclusions can be quoted.

High chromium-nickel alloys are particularly resistant to all services when chromium is 25% or more. Low carbon 18-8 is almost as resistant; carbon contents of 0.15 to 0.45 show up immediately in an accelerated weight loss. "Reverse 18-8" gives about the same test results as high carbon 18-8. All of the high chromium-irons (12% to 25% chromium) appear to be definitely of less resistance than the low carbon, 18% chromium, 8% nickel steels. The 5% chromium steel is of much lower resistance to liquid corrosion, "though it is better than plain steel, particularly where oxygen might be expected to play a considerable part, as in crude oil storage. That better material could be chosen for that service, however, at reasonable comparative cost is evi-



Pumps Handling Material in Process in Last Stages of Refining and Decolorizing Motor Lubricant

dent from the results for aluminum and galvanized iron and steel."

In plates subjected to hydrochloric acid and water containing HCl, separated from naptha, the copper-nickel alloys are better than the chromium-iron alloys; low zinc brasses are also resistant. Alloy irons, especially silicon iron, are far better than common gray iron.

Corrosion in Heat Exchangers

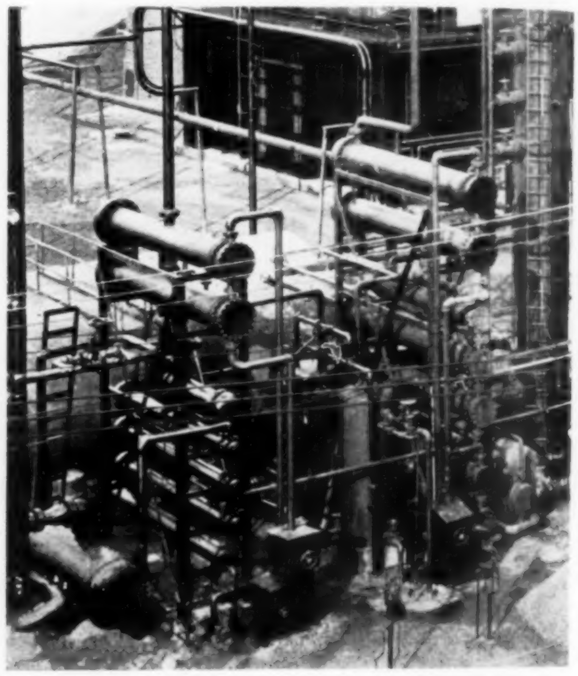
One of the "hot spots" as to corrosion troubles is found in heat exchangers. The problem was briefly discussed by H. L. Bedell of White Eagle Refining Co., Augusta, Kans. Use of heat exchangers is comparatively recent — since the development of cracking stills which required a more careful refining of the original crude and extended the distillation process to include the so-called "gas oil" fraction.

Since refining is largely a problem in fractional distillation, there is no reason why the heat in a finished vapor should not be transferred to incoming liquid. This is done in heat exchangers modelled after steam condensers used aboard ship, wherein adequate surface for transfer is obtained by grouping a large number of relatively small tubes in a bundle and placing the bundle in a suitable shell. Some early troubles with "stress corrosion" have been avoided by proper design — especially the use of floating condenser heads — and the physical needs are easily met.

The corroding media are water containing various chlorides, and oil containing some sulphur compounds. These are responsible for the presence of HCl, H_2SO_3, H_2S. "The iron which is lost from the equipment by corrosion by these reagents may cost several dollars per pound when all costs are considered." Consequently the oil is neutralized as nearly as possible with lime; the most serious problem is water, of a highly variable salt and oxygen content. Pitting of condenser tubes from the water side appears to be due to galvanic action set up by non-homogeneities in the metal. Dezincification of brass tubes may be due to this action or to general solution in very alkaline water. Spray ponds, for cooling the water prior to re-use, saturate the water with oxygen and enhance corrosion of iron and steel, especially as the temperature increases.

Many metals have been proposed and tried in condenser service. Observations on a large installation led Mr. Bedell to rank some of them as follows, in order of permanence: (1) Copper-nickel and copper-nickel-aluminum; (2) copper and copper with a small amount of arsenic or silicon — especially good at temperatures below 300° F.; (3) admiralty metal, or copper-zinc-tin, especially the low zinc varieties in oil neutralized with alkaline agents; (4) 4 to 6% chromium steel and (5) plain carbon steel.

Mr. Bedell notes how difficult it is to make an accurate comparison of life of competing metals, since failures by no means occur simultaneously. He plots a probability curve for the total number in an installation from observations on the life of a fraction of that number, and so determines the life expectancy.



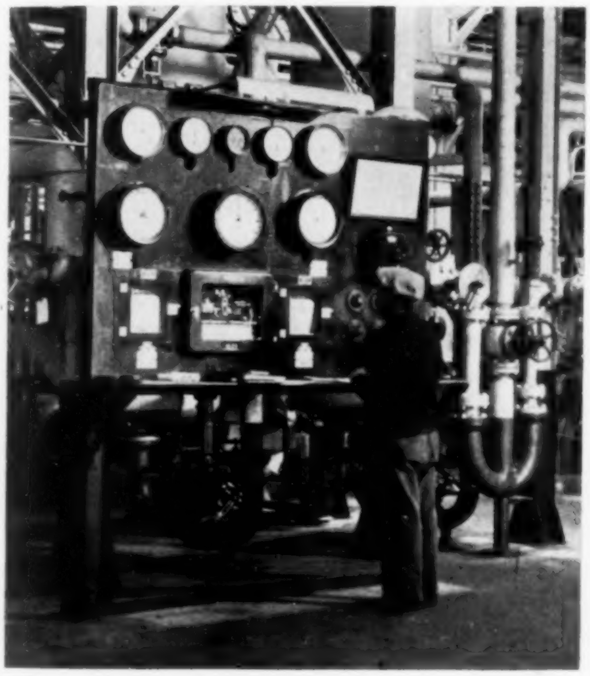
Series of Heat Exchangers, Out Doors, at Pennzoil Refinery, Near Oil City, Pa.

Metals for Pumps

A survey of the materials used in oil refinery pumps led A. E. Harnsberger of the Pure Oil Co., Chicago, to recommend that the number of hard and corrosion resisting alloys be kept at a minimum so that foundrymen could increase the tonnage of each analysis and so reduce the costs; this in turn would warrant their use in less corrosive conditions. Very important changes have recently been made by pump manufacturers, so that now a wealth of special equipment is available where 10 years ago the refiner had to adapt a standardized machine for his service. The present emphasis is therefore on cost. Neverthe-

less it will seldom be good business to cut on cost and quality to the point where standby equipment must be installed to insure against shutdown for repairs.

Pumps and the materials required depend on the operating conditions. These vary as to four principal considerations: (1) Temperature, which may be normal, as cold as —50° F., or as hot as 900° F.; (2) pressure, which ordinarily is 200 psi. but may go as high as 2000; (3) corrosion of moist oil at 250° F., or sulphur bearing fractions at 450 to 900° F.; and (4) abrasion due to metal to metal friction intensified by coke particles or slurries of Fuller's earth or copper oxide.



Not a Control for a Modern Heat Treating Furnace, But for a Solvent Recovery Unit

From the mass of specific information presented by Mr. Harnsberger, only some data concerning the most troublesome items can be presented here. He finds that the general service pumps, operating at air temperatures, are made of iron alloys rather than bronze. Hard liners and wearing rings are frequently of "ni-resist" (cast iron containing 14% nickel, 6% copper, 2% chromium). Piston rods, shaft sleeves on centrifugal pumps and shafts and impellers on rotary pumps are made of carburized S.A.E. 1020, 3140, 6150 steels, nitrided "nitralloy," or steel with a surface of "stellite" welded on. These are listed in order of the severity of the abrasive conditions to be met in non-corrosive liquids.

Reflux pumps handling fractions up to 200° F. deteriorate because the liquid contains some water and more or less acid. The valve seats and guides give as much trouble as corresponding parts on a high speed gas engine, and a wide variety of materials (some non-metallic) are in use. As to other reflux pump parts the piston rods on the fluid ends and sleeves on shafts for centrifugal pumps require frequent replacement. In handling corrosive fractions the expected life of such parts was estimated by the speaker as follows: Cold rolled steel, 1 to 3 months; porcelain coated steel, 3 to 6 months; hard chromium plate, 1 to 12 months; stainless steel spray coat, 3 to 6 months; 13% chromium steel, hardened to 450 Brinell, 6 to 12 months; 18% chromium, 8% nickel steel, 20 to 30 months. (The latter is too soft for places where abrasion is a factor.)

The liquid ends on hot oil pumps give much trouble because gritty coke is deposited from the fractions at 900° F., any corrosive material is especially active at such high temperatures, and high speed, turbid flow may cause erosion and cavitation. Hence the materials must be strong and tough at heat as well as corrosion and abrasion resistant. In general, good practice would call for a close grained cast iron for services at 400° F. and 500 psi. pressure; high test cast iron for 450° F. and 600 psi. pressure as top limit; heat treated carbon steel castings at 800° F. and 1000 psi., and heat treated alloy steel forgings for the most extreme services at 900° F. and 2000 psi. pressure. Liners, piston rods, plungers, valves, valve seats and packing also must be carefully selected. The 4 to 6% chromium, 0.5% molybdenum steel (0.25% carbon) is especially good for this service, as it is corrosion resistant yet apparently does not permit coke to attach itself very readily. Mr. Harnsberger recommends a double normalizing (1800° and 1625°) followed by a draw at 1250, furnace cooled to 700° F., for this alloy steel.

In high speed centrifugal pumps for hot oil the coefficient of expansion of all parts must be matched. Impellers of 18-8 and 25-12 have shown "no corrosion or erosion in several years operation." Many parts, like wearing rings, interstage bushings, shaft sleeves and balancing disks are of these alloys with "stellited" surfaces free of cracks. Stud bolts on such equipment are important — successful use of a steel containing 6% Cr, 0.30% C, 1% W is noted; it was heat treated to an ultimate of 140,000 psi., elastic limit of 126,000 psi., 17% elongation in 2 in., Brinell hardness 300.

Photo by Lewis W. Hine for Empire State Building, New York

Building New Things of Steel

Copper Alloyed With Steel

By C. H. LORIG
Metallurgist
Battelle Memorial Institute
Columbus, Ohio

Most iron ores contain copper in small amounts which enter the iron on reduction. Copper from this source appeared in many of the early irons, and their long life was attributed by some to the presence of copper. As certain of the old irons contained as much as 1% copper it was natural to find references in the early literature to its effect. One of the earliest (by Louis Savot, 1627) mentioned the difficulties accompanying the working of wrought iron containing copper. Later references to the subject, for steels as well as for iron, are contradictory, some alleging that copper impedes the puddling and refining process and makes steel hot short, others stating that such noxious influences do not exist. Only a few mentioned the use of copper as an effective alloying element in iron and steel.

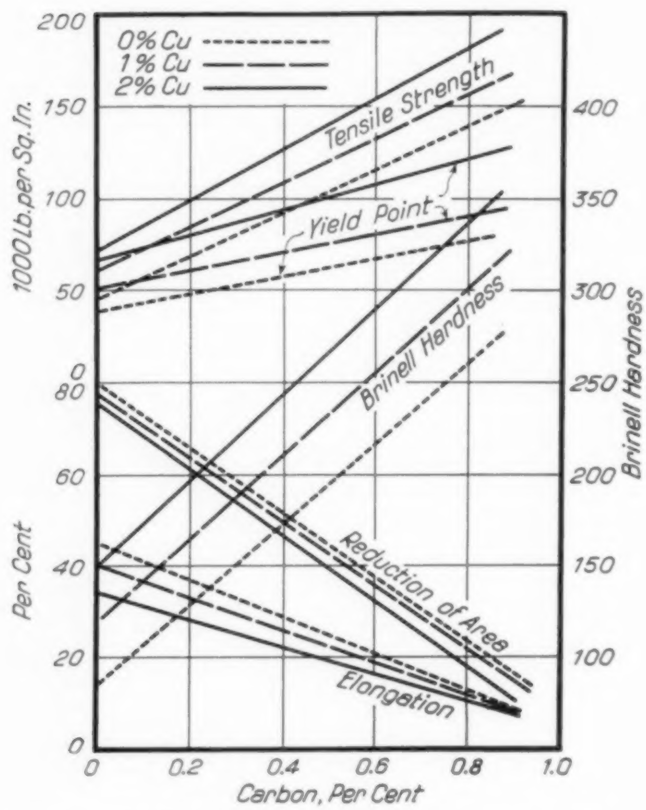
The monograph on "Alloys of Iron and Copper," recently published by Alloys of Iron Research (which is quoted freely in preparing this article) notes that H. H. Campbell in 1896 stated that the iron made from the important ore deposits near Cornwall, Pa. — only recently worked out — contained from 0.75 to 1.0% of copper, and large quantities of rails were made from this iron alone. However, at the eastern steel works it was more often the custom to use half or less of this ore in the burden; large amounts of such pig iron were made into all kinds of steels, both hard and soft, and large quantities have been cast in foundries. The Editor of Metal Progress in an article in *The Iron Age*, April 4, 1929, notes that the bessemer steel rails made in the old Lackawanna works in Scranton, Pa., contained up to 0.50 or even 0.60% copper, and an analysis of rail records reported to American Railroad Engineering Association showed their outstanding excellence in wear and in immunity to broken or split heads and transverse fissures. Even though copper might not be responsible, it certainly did not harm the metal for ultimate service.

Toward the close of the nineteenth century writings made an appearance on the influence of copper on properties of steels. Lipin in 1895 found the strength to increase and the ductility to decrease with copper content. Ball and Wingham, Campbell, Stead and Evans, Hadfield, Breuil; later Burgess and Aston, Clevenger and Ray and others published data which conclusively showed the influences on properties of alloying steel with copper. Kinnear in 1925 noted the precipitation hardening effect.

Because of its relative cheapness and its marked influence on properties recent interest in the use of copper in iron and steel has been greatly stimulated. With several of the drawbacks to the use of this element overcome through investigations which made clear their causes, commercial applications for copper steels have rapidly increased.

In the reduction of cupriferous iron ores all of the copper enters the pig iron. This is the basis for a suggestion that the introduction of copper in amounts required for the manufacture of corrosion resistant copper steels be effected by the use of copper-bearing ore in the blast furnace. Losses of copper during the making of a heat of steel are negligible, and it may be added in its metallic state as ingots, borings, scrap, or baled wire. It may be added at any period of the heat, or in the ladle.

Portion of a Manuscript Prepared for Next Edition, National Metals Handbook



While Carbon Has Great Influence on Strength, Hardness and Ductility of Steels, It Is Intensified by More Than 0.5% Copper. Tests Were Made on Forged and Rolled 1-in. Bars, Normalized at 1550° F.

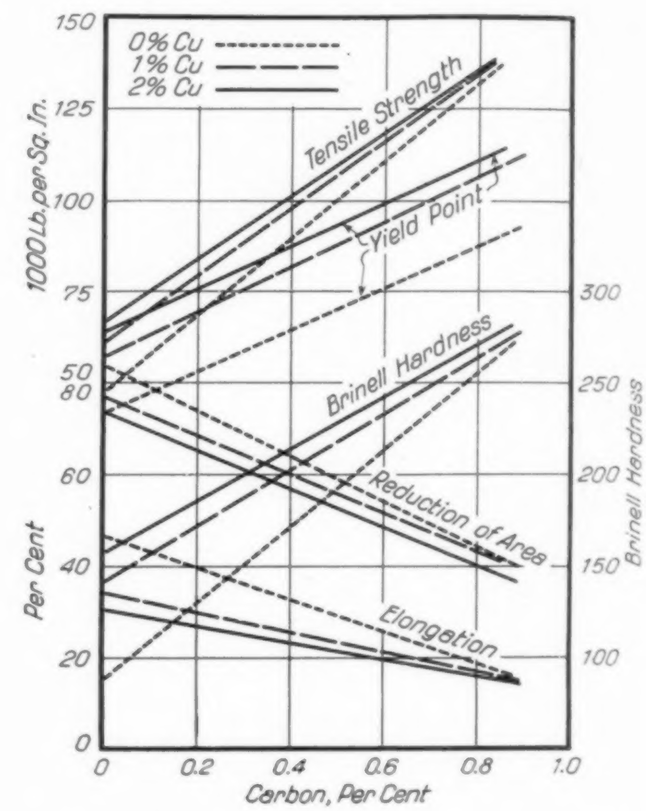
Constitution of Copper Steeels

The constitution of alloys from the iron-rich corner of the iron-copper-cementite system is quite uncertain, although Ishiwara, Yonekura and Ishigaki outlined a possible diagram. The solid phases that exist are delta iron; gamma iron or austenite; alpha iron or ferrite; iron carbide or cementite; and epsilon solid solution which contains practically no carbon and little iron. The system does not have a closed gamma loop. Carbon decreases the solubility of copper in liquid iron, thus forming a two-liquid region, and decreases the solubility of copper in solid iron, that is to say, ferrite.

From lattice constant determination, Norton found the maximum solubility of copper in alpha iron at 1560° F. to be 1.4%, and that below 1200° F. the solubility was constant at 0.35%. Because of the solubility of small quantities of copper in iron the epsilon phase exists only in steels with more than a few tenths per cent of copper. The actual existence of epsilon is determined somewhat by the heat treatment and cooling rate.

Copper raises the A_4 point and depresses the A_3 and A_1 point in steels. It also retards the transformation. The work of the Japanese investigators would indicate that the eutectoid is located approximately at 0.9% carbon, 1.9% copper and 1290° F.

The microstructure of steels containing only a small percentage of copper does not differ greatly from that of carbon steels. The only new constituent to appear, the copper-rich, solid solution epsilon, forms either as a net work or large particles during solidification and cooling, or as tiny particles, sometimes of submicroscopic dimensions, dispersed throughout the grains when precipitated from alpha iron. Extremely slow cooling and a microscope of the highest resolving power are necessary to disclose particles of epsilon in medium copper steels.



Copper Has Considerable Influence on Mechanical Properties of 1-in. Low Carbon Steel Bars When Oil Quenched From 1505° F. and Tempered 1 Hr. at 1200° F., but Comparatively Little Influence Except on Yield Strength of High Carbon Steels

Effect of Copper in Steel

No particular difficulties in the making of copper steels can be ascribed to the presence of copper, although some troubles in working at high temperatures have been noted. As an alloy-

ing element it affects the properties of steels, more particularly the corrosion resistance, mechanical properties, electric and magnetic properties and the response to heat treatment.

Heat Treatment—Microstructure of copper steels differs slightly from carbon steels because of the epsilon phase. Hot rolled or forged copper steels and those normalized or quenched do not differ greatly from carbon steels insofar as they contain such constituents as ferrite, pearlite, sorbite, martensite and other modifications common to carbon steels. Slow cooling on annealing or prolonged drawing causes the coalescence of the copper-rich solid solution (epsilon) in medium and high copper steels thereby producing appreciable changes in structure. A representative micro is shown on the next page.

The slowing of the transformation by copper permits less drastic quenching treatments and tends toward deeper hardening.

Case hardening of steels is not affected by copper, provided the surface is not oxidized and the copper content is below 3%.

Mechanical Properties — Mechanical properties of normalized and of water quenched and tempered copper-bearing, hypo-eutectoid steels are plotted in the two diagrams on page 54.

Physical properties are not much affected by less than 0.5% copper. Strength and hardness are both materially increased by 1 or 2% copper, especially in the normalized condition. Yield strength is increased more pronouncedly than the ultimate tensile strength; it may be noted that the yield strength of a 1% copper low carbon steel is higher than the ultimate strength of a similar soft steel without copper. As copper approaches 3% the normalized lower carbon steels reach their maximum strength.

In the annealed steels and those tempered after normalizing, rapid changes in properties occur with copper additions increasing from 0.5% to 1.2%. Further alloying with copper is appreciably less effective.

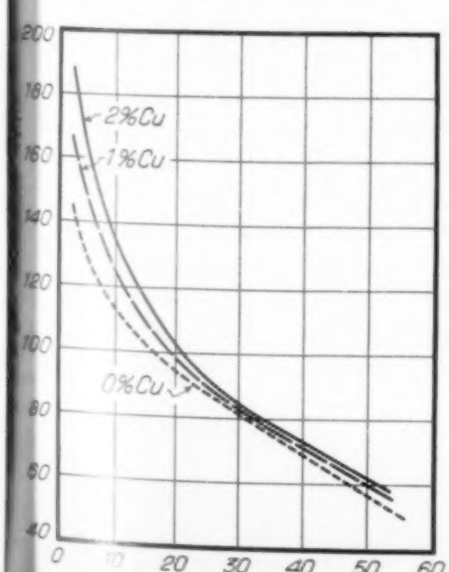


Diagram at Left Shows That Copper up to 2% Improves Toughness of Normalized Steels, When Samples of Equal Tensile Strength Are Compared. . . . At Right is Shown the Expected Change in 1.5% Copper Steel (Normalized) After Precipitation Hardening. Width of Bands Represents the Optimum Magnitude of the Changes

Per Cent Failures in Exposure Tests

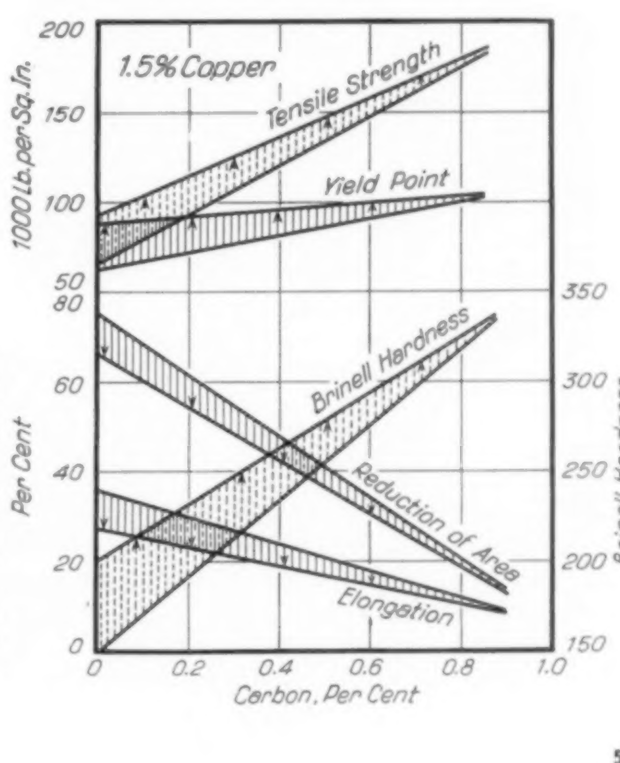
	Industrial	Rural	Marine
22 gage; copper bearing	84%	37%	3%
No copper	100	93	56
16 gage; copper bearing	0	0	0
No copper	81	3	0

The ductility of carbon steels is lowered by copper. For a given strength, copper reduces the ductility less rapidly than carbon. Put in other words, copper up to 2% improves the Charpy impact value when samples of equal strength are compared. See the third diagram for normalized steels.

Test data on comparatively high carbon steel containing up to 1.65% copper indicate no change in the endurance ratio.

Scattered information on the properties of cold worked copper steels, and on creep and high temperature tensile properties of copper steels, indicate that improvement along these lines is produced by copper.

Corrosion Resistance—Comprehensive tests begun in 1916 by the American Society for Testing Materials have definitely established the superiority of "copper-bearing" steel sheets. A summary of the results to 1933 (or to the time of abandoning the tests) is given in the adjoining table. Three localities were chosen: Pittsburgh, representing an industrial atmosphere; Fort Sheridan, Ill., representing a rural atmosphere; and Annapolis, Md., representing a marine



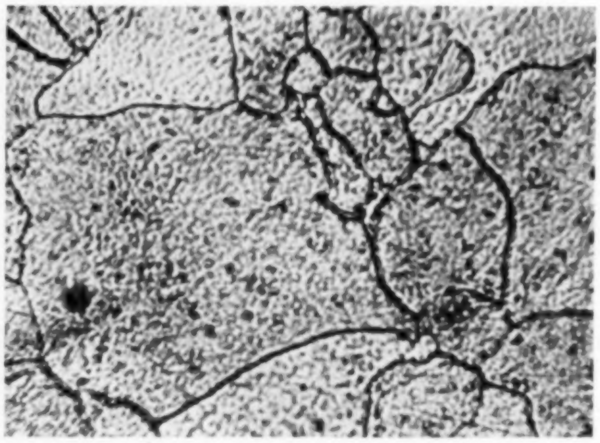
atmosphere. Tests at Pittsburgh were judged complete in 6½ years and at Fort Sheridan in 11 years, but at Annapolis (where the resistance is remarkably good) the observations are still being continued.

Much acrimonious discussion indulged in in the past can be disregarded in the light of these authoritative and impartial tests. It is definitely proven that the atmospheric resistance of steel to corrosion increases rapidly up to 0.25% copper and then more slowly for higher percentages. The resistance to corrosion continues to increase above 0.50% copper, when it is retained in solid solution in the ferrite. This is shown by weight losses of box annealed, low carbon steel sheets exposed to sea air for 10 months:

Copper Content	Loss Per Sq. Cm.
0.02%	0.0167 grams
0.20	0.0150
0.50	0.0144
1.02	0.0156
1.02	0.0136

The last one was reheated to 1440° F. after annealing and then air quenched; the reduced loss implies that atmospheric corrosion in the higher copper steels is accelerated only when the copper exists out of solid solution in the ferrite.

Numerous exposure tests have indicated that painted and galvanized surfaces are more durable on copper-bearing than on plain steels.



Microstructure (800 Magnifications) of 4% Copper Steel With 0.10% Carbon. Invisible epsilon phase darkens the ferrite on etching and spheroidizes cementite at the grain boundaries

While it is definitely established that copper increases the resistance of iron and steel to atmospheric corrosion, the results of submerged corrosion tests are not in good agreement. The influence of copper under the latter conditions is secondary to and is masked by variations in external conditions such as oxygen concentration, mill scale and location of the tests.

In summarizing the U. S. Bureau of Standards' investigation of soil corrosion, Logan stated that copper-bearing steel does not appear to be superior when buried in soil, perhaps because of the limited supply of oxygen.

Hot Working Properties—The reputed hot shortness in the low and medium copper steels does not exist. Although cracks appear on the edge and surface of steels containing as little as 0.20% copper during forging or rolling above 2000° F., they are caused by the intergranular penetration of copper deposited beneath the scale. This intergranular penetration of copper (epsilon phase) and the surface cracking may be corrected by adding small amounts of nickel, by working below the melting temperature of the copper-rich solid solution (approximately 2000° F.), or by preventing the formation of scale on the steel, which enriches the surface layers in copper because of preferential oxidation of iron and carbon.

Steels containing several per cent of copper, on the other hand (owing to the occurrence of intergranular, copper-rich solid solution), may be distinctly hot short at working temperatures.

Weldability—Fusion welding of steel is not influenced by copper in amounts at least up to 0.75%, except that the metal deposited in the weld may be strengthened by copper.

Precipitation Hardening

Since the solubility of copper in ferrite decreases as the temperature drops from the lower critical to about 1100° F., steels containing from 0.6 to about 4.0% copper may be hardened by cooling and aging at moderate temperature. These phenomena of precipitation hardening are most apparent in low carbon steels with from 1.2 to 1.5% copper. As pointed out by Dr. Merica in recent articles in Metal Progress, the process involves the transformation of a supersaturated solid solution.

To produce a supersaturated solid solution of copper in iron which will respond to a precipitation hardening treatment it is not necessary to quench from a high temperature. In low carbon steels the magnitude of the hardening effect upon aging does not decrease unless the metal has been *very* slowly cooled after the solution heat treatment. Some hardening occurs even after cooling at 1° F. per minute. *(Continued on page 78)*

New S. A. E. Steels

By FRANK P. GILLIGAN
Past President
American Society for Metals
Chairman, Standards Committee
Society of Automotive Engineers

EDITOR'S NOTE: Through the kindness of R. S. Burnett, Standards Manager, Society of Automotive Engineers, and Norman G. Shidle, Executive Editor, S.A.E. *Journal*, METAL PROGRESS is enabled to present to members of American Society for Metals the new list of S.A.E. steels and Frank Gilligan's article simultaneously with their publication in the *Journal*. The tables are printed here in such a manner that they may be cut out and tipped into the National Metals Handbook at page 418.

The S.A.E. Handbook, 1935 edition, will contain about 100 pages devoted to steel, malleable iron and gray iron. A great number of heat treatments (sometimes as many as five for a single steel like 1020) are described in detail, and each steel has a chart of physical properties. In many instances these have been redrawn; if the steel may be quenched either in oil or water, the chart shows properties for both treatments.

IT IS NOW NEARLY THIRTY YEARS SINCE a group of automobile engineers, known as the Mechanical Branch of the Association of Licensed Automobile Manufacturers, engaged the late Henry Souther as consulting metallurgist and called into conference several steel mill representatives to discuss the need for chemical specifications for steels that would be suitable for various automobile parts.

At that time the commercial structural steels were chiefly of the carbon steel type and were quite generally sold on the basis of physical properties in the condition as delivered to the purchaser. Alloy steels were merchandised under trade names and each producer used an analysis that differed slightly but significantly from his competitor's. The art of heat treatment as applied outside the toolroom or blacksmith shop was in its infancy, and amidst the known and unknown variations in the steels used and the frequent absence of pyrometers on furnaces difficult to control, the engineer and the production departments were almost continually in hot water — which may explain why so many shop executives were considered "hard boiled"! Conse-

Carbon Steels

S.A.E. No.	Carbon Range	Manganese Range	Phosphorus Max.	Sulphur Max.
1010	0.05-0.15	0.30-0.60	0.045	0.055
1015	0.10-0.20	0.30-0.60	0.045	0.055
X1015	0.10-0.20	0.70-1.00	0.045	0.055
1020	0.15-0.25	0.30-0.60	0.045	0.055
X1020	0.15-0.25	0.70-1.00	0.045	0.055
1025	0.20-0.30	0.30-0.60	0.045	0.055
X1025	0.20-0.30	0.70-1.00	0.045	0.055
1030	0.25-0.35	0.60-0.90	0.045	0.055
1035	0.30-0.40	0.60-0.90	0.045	0.055
1040	0.35-0.45	0.60-0.90	0.045	0.055
X1040	0.35-0.45	0.40-0.70	0.045	0.055
1045	0.40-0.50	0.60-0.90	0.045	0.055
X1045	0.40-0.50	0.40-0.70	0.045	0.055
1050	0.45-0.55	0.60-0.90	0.045	0.055
X1050	0.45-0.55	0.40-0.70	0.045	0.055
1055	0.50-0.60	0.60-0.90	0.040	0.055
X1055	0.50-0.60	0.90-1.20	0.040	0.055
1060	0.55-0.70	0.60-0.90	0.040	0.055
1065	0.60-0.75	0.60-0.90	0.040	0.055
X1065	0.60-0.75	0.90-1.20	0.040	0.055
1070	0.65-0.80	0.60-0.90	0.040	0.055
1075	0.70-0.85	0.60-0.90	0.040	0.055
1080	0.75-0.90	0.60-0.90	0.040	0.055
1085	0.80-0.95	0.60-0.90	0.040	0.055
1090	0.85-1.00	0.60-0.90	0.040	0.055
1095	0.90-1.05	0.25-0.50	0.040	0.055

Free Cutting Steels

S.A.E. No.	Carbon Range	Manganese Range	Phosphorus Range	Sulphur Range
1112	0.08-0.16	0.60-0.90	0.09-0.13	0.10 -0.20
X1112	0.08-0.16	0.60-0.90	0.09-0.13	0.20 -0.30
1115	0.10-0.20	0.70-1.00	0.045 max.	0.075-0.15
1120	0.15-0.25	0.60-0.90	0.045 max.	0.075-0.15
X1314	0.10-0.20	1.00-1.30	0.045 max.	0.075-0.15
X1315	0.10-0.20	1.30-1.60	0.045 max.	0.075-0.15
X1330	0.25-0.35	1.35-1.65	0.045 max.	0.075-0.15
X1335	0.30-0.40	1.35-1.65	0.045 max.	0.075-0.15
X1340	0.35-0.45	1.35-1.65	0.045 max.	0.075-0.15

S. A. E. Standards Committee; Iron and Steel Division

F. P. GILLIGAN, *Chairman*, Henry Souther Engineering Corp.

E. F. DAVIS, *Vice-Chairman*, Warner Gear Co.

J. R. Adams
The Midvale Co.

A. L. Boegehold
General Motors Corp.

H. Bornstein
Deere & Co.

H. T. Chandler
Vanadium Corp. of America

Bishop Clements
Wright Aeronautical Corp.

A. T. Colwell
Thompson Products Co.

A. H. d'Arcambal
Pratt & Whitney Co.

William Davis
Pittsburgh Crucible Steel Co.

B. H. DeLong
Carpenter Steel Co.

N. L. Deuble
Republic Steel Corp.

H. J. Fishbeck
Pratt & Whitney Aircraft Co.

H. W. Graham
Jones & Laughlin Steel Corp.

W. J. Harris
Studebaker Corp.

W. G. Hildorf
Timken Steel & Tube Co.

A. J. Herzig
Climax Molybdenum Co.

E. J. Janitzky
Illinois Steel Co.

J. B. Johnson
War Dept., Air Corps

G. E. Knable
Carnegie Steel Co.

H. B. Knowlton
International Harvester Co.

F. E. McCleary
Dodge Bros.

O. W. McMullan
Timken Detroit Axle Co.

J. G. Morrow
Steel Co. of Canada

R. B. Schenck
Buick Motor Co.

E. W. Upham
Chrysler Corp.

J. M. Watson
Hupp Motor Car Corp.

T. H. Wickenden
International Nickel Co.

Henry Wysor
Bethlehem Steel Co.

Manganese Steels

See Note (a) for Silicon Content

No.	Carbon	Manganese	Phosphorus	Sulphur
T1330	0.25-0.35	1.60-1.90	0.040 max.	0.050 max.
T1335	0.30-0.40	1.60-1.90	0.040 max.	0.050 max.
T1340	0.35-0.45	1.60-1.90	0.040 max.	0.050 max.
T1345	0.40-0.50	1.60-1.90	0.040 max.	0.050 max.
T1350	0.45-0.55	1.60-1.90	0.040 max.	0.050 max.

Nickel Steels

See Notes (a) and (b) for Silicon, Phosphorus and Sulphur Content

No.	Carbon	Manganese	Nickel
2015	0.10-0.20	0.30-0.60	0.40-0.60
2115	0.10-0.20	0.30-0.60	1.25-1.75
2315	0.10-0.20	0.30-0.60	3.25-3.75
2320	0.15-0.25	0.30-0.60	3.25-3.75
2330	0.25-0.35	0.50-0.80	3.25-3.75
2335	0.30-0.40	0.50-0.80	3.25-3.75
2340	0.35-0.45	0.60-0.90	3.25-3.75
2345	0.40-0.50	0.60-0.90	3.25-3.75
2350	0.45-0.55	0.60-0.90	3.25-3.75
2515	0.10-0.20	0.30-0.60	4.75-5.25

Nickel-Chromium Steels

See Notes (a) and (b) for Silicon, Phosphorus and Sulphur Content

No.	Carbon	Manganese	Nickel	Chromium
3115	0.10-0.20	0.30-0.60	1.00-1.50	0.45-0.75
3120	0.15-0.25	0.30-0.60	1.00-1.50	0.45-0.75
3125	0.20-0.30	0.50-0.80	1.00-1.50	0.45-0.75
3130	0.25-0.35	0.50-0.80	1.00-1.50	0.45-0.75
3135	0.30-0.40	0.50-0.80	1.00-1.50	0.45-0.75
3140	0.35-0.45	0.60-0.90	1.00-1.50	0.45-0.75
X3140	0.35-0.45	0.60-0.90	1.00-1.50	0.60-0.90
3145	0.40-0.50	0.60-0.90	1.00-1.50	0.45-0.75
3150	0.45-0.55	0.60-0.90	1.00-1.50	0.45-0.75
3215	0.10-0.20	0.30-0.60	1.50-2.00	0.90-1.25
3220	0.15-0.25	0.30-0.60	1.50-2.00	0.90-1.25
3230	0.25-0.35	0.30-0.60	1.50-2.00	0.90-1.25
3240	0.35-0.45	0.30-0.60	1.50-2.00	0.90-1.25
3245	0.40-0.50	0.30-0.60	1.50-2.00	0.90-1.25
3250	0.45-0.55	0.30-0.60	1.50-2.00	0.90-1.25
3312	max. 0.17	0.30-0.60	3.25-3.75	1.25-1.75
3325	0.20-0.30	0.30-0.60	3.25-3.75	1.25-1.75
3335	0.30-0.40	0.30-0.60	3.25-3.75	1.25-1.75
3340	0.35-0.45	0.30-0.60	3.25-3.75	1.25-1.75
3415	0.10-0.20	0.30-0.60	2.75-3.25	0.60-0.95
3435	0.30-0.40	0.30-0.60	2.75-3.25	0.60-0.95
3450	0.45-0.55	0.30-0.60	2.75-3.25	0.60-0.95

quently, when the engineer of that day desired to change his source of steel supply he had good reason to hesitate lest his last state be worse than his first.

The steel companies, having considerable ordnance and tool steel experience, recognized the problem, and willingly cooperated in the development of a group of chemical specifications for both carbon and alloy steels which enabled the automobile engineer to exercise some choice in the type of steel used and in the range of physical properties produced by suitable heat treatment. They also assisted in the preparation of recommended methods of heat treatment.

That group eventually developed into the S.A.E. Iron and Steel Division, and its first report under that title was published in 1911. It covered seven carbon and eleven alloy steels. In 1912 the S.A.E. numbering system for steel was adopted, and in 1915 the first physical property charts were published.

Since then the use of the S.A.E. steels has increased enormously and has extended to practically every field of consumption where heat treatment is an essential part of production. The same art of heat treatment that brought these steel specifications into existence has promoted their general use and made them a part of the daily language of every metallurgist. As a result of this popularity, of their general appropriateness for all types of construction, and convenience of identification they enjoy international recognition.

The last previous extensive revision of the list was made in 1922. Since that time research by both steel user and steel maker has brought forth new steels, as well as modifications in and refinements of many of the long established compositions. A series of heat and corrosion resisting alloys has been added. Advantage has been taken of the results of extensive research in the melting and finishing operations of steel making and a system of grain size control adopted for their purchase. The lists on these pages, therefore, recognize and record important advances in the art of steel making and utilization.

Limits Acceptable to Producers

The significance of the changes made may be summarized briefly. These specifications now cover the carbon range from 0.05% minimum to 1.05% maximum in the carbon series, with sufficient variation in the manganese and sulphur contents to meet the needs. The compositions standardized conform to the Steel Code requirements for each type, hence there is no necessity for any user to pay a special price because of unusual limits.

In the alloy series a greatly increased and diversified list of compositions is provided, including heat resisting and corrosion resisting alloys. For every application the user has a wide choice as to type of alloy steel, range of physical properties, and material cost. No steel maker or alloy producer is subjected to discrimination. The engineer or designer has only to determine his service stress and other essential requirements, make his selection of acceptable steels, and leave the rest to the purchasing and metallurgical departments. This is in marked contrast with the early days of the automobile industry, when the engineer had to use a different composition every time he changed his source of supply.

The engineer or metallurgist who desires to select his steel upon the basis of physical values may begin with a plain carbon steel with a tensile strength around 45,000 psi. and gradually ascend the scale of strengths to the highest values — 250,000 psi. or even higher — and have available a choice of two or more compositions every step of the way. Excellent alloy steels are now provided for the heaviest of automotive sections. Hence, the engineer or the metallurgist is not confined to a single type of steel or to a single supplier.

It is well understood that composition, as measured by the elements covered in chemical specifications, is not synonymous with quality. The elements commonly included in specifications of this character enable the user and the maker to arrive at a common understanding as to the type and grade of steel desired. The particular *quality* a purchaser obtains will depend upon his own and his supplier's knowledge of the specific requirements, reinforced by such inspection requirements as he may impose.

Of course, under the Steel Code, the imposition of special quality tests, as for example, the test as to grain size, or microscopic and macroscopic examinations, necessitates the payment of certain standardized extras. It therefore behooves each steel user to identify and to establish in definite values or terms his particular engineering and metallurgical requirements, keeping in mind that a design which is poorly balanced or provides an inadequate factor of safety usually leads to the application of severe quality stand-

Molybdenum Steels

See Notes (a) and (b) for Silicon, Phosphorus and Sulphur Content

S.A.E. No.	Carbon	Manganese	Chromium	Nickel	Molybdenum
4130	0.25-0.35	0.50-0.80	0.50-0.80	....	0.15-0.25
X4130	0.25-0.35	0.40-0.60	0.80-1.10	....	0.15-0.25
4135	0.30-0.40	0.60-0.90	0.80-1.10	....	0.15-0.25
4140	0.35-0.45	0.60-0.90	0.80-1.10	....	0.15-0.25
4150	0.45-0.55	0.60-0.90	0.80-1.10	....	0.15-0.25
4340	0.35-0.45	0.50-0.80	0.50-0.80	1.50-2.00	0.30-0.40
4345	0.40-0.50	0.50-0.80	0.60-0.90	1.50-2.00	0.15-0.25
4615	0.10-0.20	0.40-0.70	....	1.65-2.00	0.20-0.30
4620	0.15-0.25	0.40-0.70	....	1.65-2.00	0.20-0.30
4640	0.35-0.45	0.50-0.80	....	1.65-2.00	0.20-0.30
4815	0.10-0.20	0.40-0.60	....	3.25-3.75	0.20-0.30
4820	0.15-0.25	0.40-0.60	....	3.25-3.75	0.20-0.30

Chromium Steels

See Note (a) for Silicon Content

S.A.E. No.	Carbon Range	Manganese Range	Phosphorus Max.	Sulphur Max.	Chromium Range
5120	0.15-0.25	0.30-0.60	0.040	0.050	0.60-0.90
5140	0.35-0.45	0.60-0.90	0.040	0.050	0.80-1.10
5150	0.45-0.55	0.60-0.90	0.040	0.050	0.80-1.10
52100	0.95-1.10	0.20-0.50	0.030	0.035	1.20-1.50

Chromium-Vanadium Steels

See Notes (a) and (c) for Silicon, Phosphorus and Sulphur Content

S.A.E. No.	Carbon Range	Manganese Range	Chromium Range	Vanadium Minimum	Vanadium Desired
6115	0.10-0.20	0.30-0.60	0.80-1.10	0.15	0.18
6120	0.15-0.25	0.30-0.60	0.80-1.10	0.15	0.18
6125	0.20-0.30	0.60-0.90	0.80-1.10	0.15	0.18
6130	0.25-0.35	0.60-0.90	0.80-1.10	0.15	0.18
6135	0.30-0.40	0.60-0.90	0.80-1.10	0.15	0.18
6140	0.35-0.45	0.60-0.90	0.80-1.10	0.15	0.18
6145	0.40-0.50	0.60-0.90	0.80-1.10	0.15	0.18
6150	0.45-0.55	0.60-0.90	0.80-1.10	0.15	0.18
6195(c)	0.90-1.05	0.20-0.45	0.80-1.10	0.15	0.18

ards, with consequent purchasing penalties. Close cooperation with the steel maker will promote a common understanding of the essential facts and help avoid charges for unnecessary extras.

One frequently hears the criticism — "There are too many steels included in the S.A.E. specifications." Looking at the matter from the standpoint of ultimate economy that statement may be true. The standards committee, however, has no mandate to dictate to the steel user just what steel he shall use for his particular application, nor has it any mandate to limit the steel maker as to the compositions he shall make. Its job is to bring the various users and makers of each type or grade to an agreement upon a common chemical specification for that steel. It does require that a steel shall have attained a significant volume of production or be generally recognized as necessary before it is established as an S.A.E. steel. Thus, while these specifications provide 109 steels, the current commercial compositions for a single steel have been reduced from as many as nine to one.

Each user has his preferred steel compositions and each steel company has its particular group of steels upon which it specializes and endeavors to develop continually in the direction of improved quality. To attempt at this time to reduce substantially the varieties of steels in these specifications would not be desirable standardization. Its effect would be to stifle progress rather than to promote it.

According to a prominent steel executive, "This is an age of tailor-made steels." Such is not the ideal production schedule a steel maker ordinarily strives for. It is a condition bred by intensive competition arising from subnormal steel consumption and it is working to the advantage of the steel consumer from a quality standpoint. Competition is not now confined to the price field, it is a question of quality and service, hence we have the competition of one steel against another, of one alloy against another, and finally, and most important, of the research facilities of one steel company against the research facilities of its competitor. Out of all this we are destined to have more steels before we have less.

Economies from Simplification

Simplification, if it comes, will require the sympathetic interest and active cooperation of engineers and metallurgists in the steel consuming industries. There will be the need for them to supply precise information on the fundamental requirements of each type of steel as to service and manufacture, to supplement similarly unbiased data on economy of production and uniformity of quality to be provided by the steel maker. There will be required more facts and fewer opinions from both groups concerning the advantages and disadvantages of the various strengthening elements, with a general willingness to compromise upon a few steels rather than an insistence upon many.

Such simplification would eliminate unnecessary fashions in tailor-made steels, reduce inventories of makers and users, and in time lead to a substantial decrease in the varieties of steels, with consequent increase in the volume of approved types. Decreasing the varieties and increasing the volume is the usual route toward profits. Profits would not be unwelcome to the steel maker, and they should lead to advantages for the steel consumer.

Tungsten Steels

See Notes (a) and (d) for Silicon, Phosphorus and Sulphur Content

No.	Carbon	Manganese	Chromium	Tungsten
71360	0.50-0.70	0.30 max.	3.00-4.00	12.00-15.00
71660	0.50-0.70	0.30 max.	3.00-4.00	15.00-18.00
7260	0.50-0.70	0.30 max.	0.50-1.00	1.50- 2.00

Silicon-Manganese Steels

See Notes (a) and (b) for Silicon, Phosphorus and Sulphur Content

No.	Carbon	Manganese	Silicon
9255	0.50-0.60	0.60-0.90	1.80-2.20
9260	0.55-0.65	0.60-0.90	1.80-2.20

Corrosion and Heat Resisting Alloys

See Note (e) for Silicon, Phosphorus and Sulphur Content

No.	Carbon	Manganese	Chromium	Nickel
30905	0.08 max.	0.20-0.70	17.00-20.00	8.00-10.00
30915	0.90-0.20	0.20-0.70	17.00-20.00	8.00-10.00
51210	0.12 max.	0.60 max.	11.50-13.00	....
X51410	0.12 max.	0.60 max.	13.00-15.00	....
51335	0.25-0.40	0.60 max.	12.00-14.00	....
51510	0.12 max.	0.60 max.	14.00-16.00	....
51710	0.12 max.	0.60 max.	16.00-18.00	....

Notes to Tables of Chemical Composition

Note (a). Silicon range of all S.A.E. basic open-hearth alloy steels shall be 0.15 to 0.30%. For electric furnace alloy steels and acid open-hearth alloy steels, the silicon content shall be 0.15% minimum.

Note (b). Phosphorus and sulphur in all S.A.E. nickel steels, nickel-chromium steels, molybdenum steels and silicon-manganese steels shall be 0.040% max. and 0.050% max. respectively.

Note (c). Phosphorus in all S.A.E. chromium-vanadium steels shall be 0.040% max. except in No. 6195, which shall be 0.030% max. Sulphur in all S.A.E. chromium-vanadium steels shall be 0.050% max. except in No. 6195, which shall be 0.035% max.

Note (d). Phosphorus and sulphur in all S.A.E. tungsten steels shall be 0.035% and 0.040% max. respectively.

Note (e). Silicon shall be 0.50% max. except in alloys 30905 and 30915, which may be 0.75% max. Phosphorus shall be 0.030% max. in all corrosion and heat resisting alloys. Sulphur shall be 0.030% max. in all except in the free cutting alloy X51410, which shall be in the range 0.15 to 0.50%.

Book Reviews

Seamless Tubes

MANUFACTURE OF SEAMLESS TUBES, FERROUS AND NON-FERROUS, by Gilbert Evans. Published by H. F. & G. Witherby, London, W. C., England. 187 pp., 7½x10 in. Price 40 shillings.

AS the reviewer knows from several unsuccessful efforts, it is rarely possible to induce a successful engineer of ripe age to write a book, or even an article or two, about the things he has worked with and knows best. Many of them have let their literary ability atrophy; others are unwilling to tackle the difficult task of sifting the essential from the non-essential and then presenting the entire matter in an orderly and logical way. They cannot help but realize how far from perfect their best efforts would be; having always demanded excellence from themselves and associates in their professional life, they naturally avoid any writing that will not reflect this high standard.

Nevertheless such writings, when they do appear, are of enormous value, and Mr. Evans' little volume is most welcome. His connection with the seamless tube industry began in 1887 when he was employed as mechanic and draftsman by the Landore Siemens Steel Co., in Wales, then only recently acquired by the German Mannesmann company for exploiting their new rotary piercing process. He thus was associated with R. C. Stiefel, chief draftsman at that plant, whose American patents caused long litigation. Others of the Landore staff who have figured in the development of the art include J. A. Charnock, and the author himself, whose improvements to the driving mechanisms and the mills generally are widely adopted, especially by non-ferrous tube manufacturers. Landore proved to be the cradle of the English and American art, and his account of the development of tube piercing processes is therefore of the greatest importance.

One would judge that the author believes that the Ehrhardt process, as improved by Wellman-Seaver and Peters, will eventually dominate the field, as far as tubes of butt-weld diameters are concerned. In this a square billet is pierced by a punch into a "bottle," and punch and bottle removed from the hydraulic press and pushed through a series of ring dies and a reeling machine, which latter loosens the tube from the punch (now acting as a mandrel). Subsequent operations of rolling down or drawing are as in any other tube mill. Mr. Evans says this is as cheap as modern butt-welding or electric welding processes, and makes a better product.

More than half of the book is devoted to non-ferrous tubes, with which the author has long been engaged as manager of Yorkshire Copper Works. This portion of the book contains many useful pages about draw bench practice — a matter not discussed in detail in the account of steel mills, doubtless because of the limitations of his experience. That is doubtless the reason why the reverberatory type of melting is described in detail, with only the slightest mention of the electric induction furnaces practically standard in America, and no mention is made of bright annealing of copper and brass tubes, which is done in all our modern mills.

The author, however, is to be respected rather than criticized for these omissions. It is far better to write about what one knows about than to write about what one has read about.

Die Casting For Users

DIE CASTINGS, THEIR DESIGN, COMPOSITION, APPLICATION, SPECIFICATIONS, TESTING AND FINISHING, by Herbert Chase. 256 pages, 6x9 in. John Wiley & Sons, New York. Price, $3.50.

Reviewed by D. L. COLWELL
Stewart Die Casting Corp., Chicago

THIS is a volume frankly aimed at supplying information on the proper application and specification of die castings to those who are not familiar with the possibilities of their wide use nor with their limitations. It is not a handbook for those who contemplate their manufacture, but

it contains valuable information for engineers and others interested in the design of metal parts. At the very start it summarizes the advantages of die castings and emphasizes the importance of knowledge and experience in their manufacture. Their advantages may be entirely lost or their use may result in expensive failure if they are not made by a competent and experienced organization. The author then lists numerous successful applications of the process, with a brief description of each. This portion of the text is profusely illustrated, and a study of the pictures alone would give the uninitiated an idea of the present scope of manufacture.

The third chapter deals with the alloys used, classifying them by the base metal in each variety. There are separate discussions of zinc, aluminum, copper, tin, lead and magnesium alloys, with considerable information about specifications of the A.S.T.M. and the S.A.E. Of course, the zinc and aluminum sections are by far the most important, and the author gives them the most attention. These two sections are gravely weakened, however, by the free use of the trade names of one of the leading zinc producers and one of the leading aluminum producers. Credit is frankly given to the advertising publications of these two companies and much of the information, therefore, savors of propaganda.

Particularly is the inclusion of the "No. 6" alloy (Tables I and II on pages 102 and 105) to be regretted; the author hints at an apology for this on a later page. This alloy was definitely rejected by the Committee B-6 of the American Society for Testing Materials several years ago, and its inclusion and recommendation (at least by inference) in this chapter seriously weakens the whole section on zinc base die castings.

Another chapter deals with casting design — and this is undoubtedly the most interesting to the designing engineer. It is well and profusely illustrated, and the examples given are typical. Probably the underlying reason for a chapter dealing with specifications is the necessity for proper precautions in the purchase of zinc base castings, as the remainder is rudimentary. The important information in this chapter could well have been covered in the discussion on alloys.

Finally there is rather a rambling discussion of finishes for die castings. It is, however, extremely interesting, and covers the subject probably as well as it can be covered at the present time. Here methods and processes are explained in greater detail, as the finishing is usually a problem to be met by the user of the die casting. Both electroplating and organic finishes are discussed.

The volume is attractively printed and easily read. The inaccuracies are remarkably few and are so unimportant that a reviewer would be small indeed to mention them. The library of every metal fabricating plant should have one.

Lake Copper

Arsenical and Argentiferous Copper, by J. L. Gregg. American Chemical Society, Monograph Series No. 67. Published by Chemical Catalog Co., New York. 189 pages, 6x9 in. Price $4.00.

THIS is another book in the series of monographs started in 1919 wherein subdivisions of chemical science are dealt with by specialists. Some of them are more scientific than industrial; others, like this one, take up some branch of technology connected with chemistry. (Metals and metallurgy are still regarded by many as minor subdivisions of chemistry.) All are intended to be written in concise, readable form so that men in branches of work only distantly related to the subject in hand may read with profit and extract useful ideas.

Mr. Gregg utilizes the same literary technique already familiar to those who have seen the monographs issued by the Alloys of Iron Research. As in them, the text is based on a series of critical reviews of existing literature. Mr. Gregg had the advantage of close cooperation of the staff of Calumet & Hecla Consolidated Copper Co., which guarantees that the text is much more than the production of library workers. At times, however, the suspicion exists that Calumet & Hecla's "lake copper" is putting its best foot forward.

It is perhaps necessary to explain to some that "lake copper" — that is, originating in the deposits of native copper in Michigan — has since the first commanded a premium over other much less pure coppers refined solely by furnace methods. A small premium has been paid for it even over the somewhat purer copper refined for the last 40 years by electrolysis, a fact which has been used as a text for many a homily on the rock-bound conservatism of the copper and brass fabricating industry. It has also been suspected that much electrolytic copper was shipped through the Lake Superior region, acquiring the designation "lake" and the premium thereby!

The metallic copper of the Lake Region con-

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tains a little silver and a little arsenic. In most veins insufficient silver is contained to pay for its recovery by electrolysis; arsenic in the ore is variable but furnace refining under soda ash removes it to low and controllable quantities.

Now as to the influence of these two impurities on the principal properties, electrical conductivity and workability: Silver, being a very good conductor and soluble in copper, has no observable effect on conductivity. Arsenic, on the other hand, is definitely objectionable, and for electrical purposes is refined very low, even down to 0.002% or lower.

As to its uses for tube, sheet, and wire (especially in the phosphorized or deoxidized form), where mechanical rather than electrical properties are demanded, it may be said that the arsenical coppers are easy to roll, stamp, and draw, and have a higher annealing temperature, greater strength and resistance to wear than has electrolytic copper. Hence many fabricators and engineers favor lake copper for deep draw stock, for boiler stays and tubes, and for roofing.

New Alloys

THE ALLOYS OF IRON AND COPPER, by J. L. Gregg and B. N. Daniloff. Monograph Series, Alloys of Iron Research. 450 pages, 6x9 in. Published for the Engineering Foundation by McGraw-Hill Book Co., New York. Price $5.

THIS book maintains the high standard of the monographs previously published in this series under Frank T. Sisco's editorial direction. In one respect it is different in content, for its predecessors were critical reviews of a large body of existing literature. Copper has no such background, and this book therefore has a large proportion of information developed in recent years and published here for the first time. Much of this research has been done at Battelle Memorial Institute under Dr. Lorig's direction and sponsored by the Copper and Brass Research Association, and the article by him on page 53 of this issue is about the best review of the monograph that could be written.

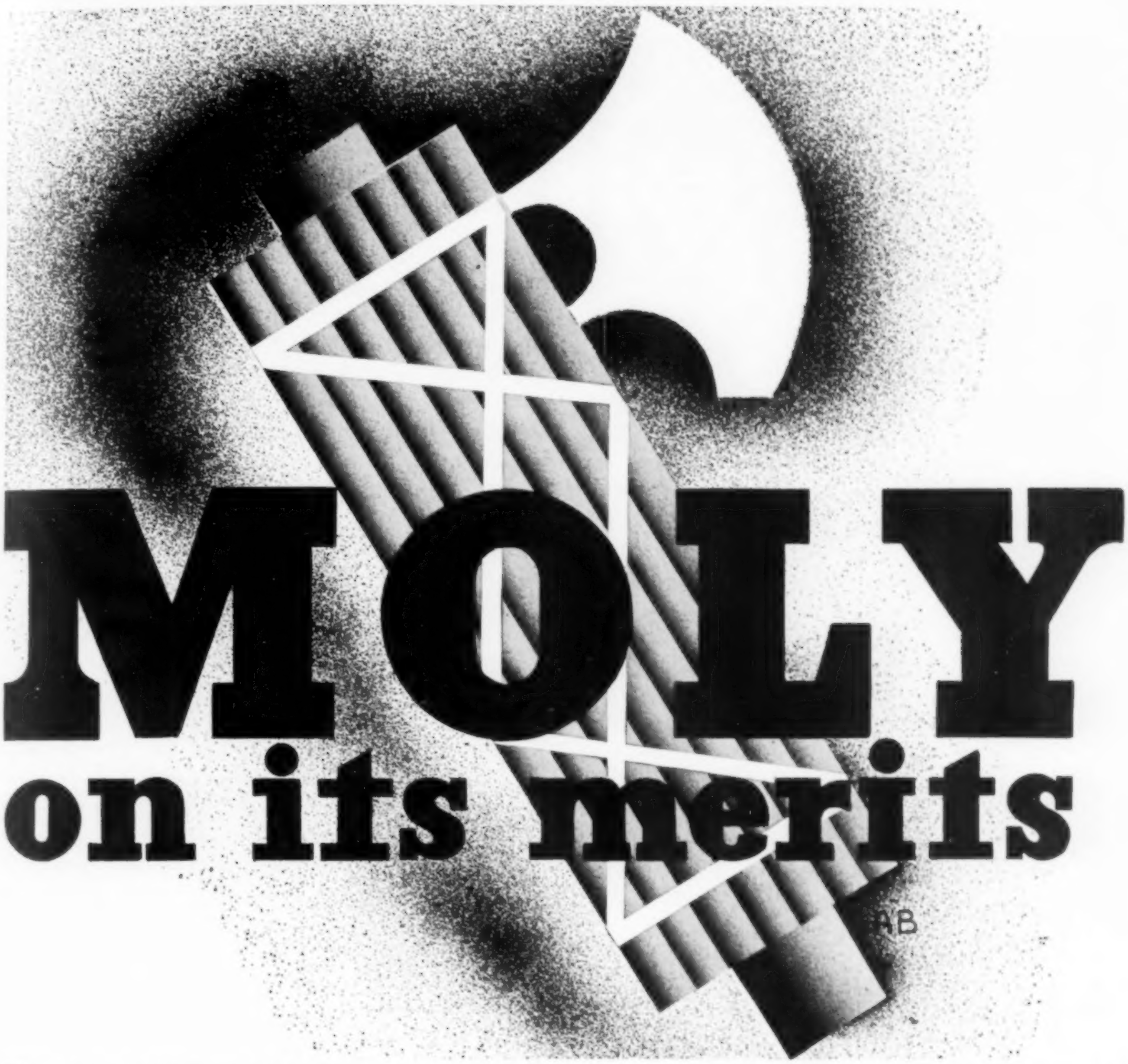
It is certain that the very interesting age hardening properties of the medium copper steels will be put to good use in the near future, and increase the use of copper as an alloy in steel to an important outlet of metal. It is a new fact, of enormous potentiality. It is encouraging that the copper industry, through the leadership of Dr. H. Foster Bain, Director of Copper and Brass Research Association, has paid the bill for finding out a lot about medium copper steel. It appears to have at last awakened to the possibilities of extending the market by studying the properties and utility of the copper alloys from the customer's viewpoint. Formerly their best men were intent upon business economies through mergers and centralized control, and upon production economies through improved methods to mine, concentrate, smelt and refine the ever leaner ores. When the copper industry generally is able to look upon marketing problems in the way its competitors in the nickel, aluminum and zinc industry do, copper will be doing bigger and better things.

X-Ray Analysis of Crystal Structure

TWO books concerning the atomic structure of crystals have recently been published. One is a 700-page volume, "A Study of Crystal Structure and Its Applications" by Wheeler P. Davey of Pennsylvania State College, published by McGraw-Hill Book Co., New York ($7.50). The other is a little book and carries on where Dr. Davey leaves off; it is "Crystal Chemistry" by O. Hassel of the University of Oslo, translated by R. C. Evans and published by William Heinemann, London (6 shillings).

Of the older generation, only those studying to be geologists or mining engineers got close enough to crystallography in their undergraduate days to be able to understand the difference between a crystal in the tetragonal and the cubic system, and to identify it by the shape of one or two fragmentary faces or the markings on them. Chemists had for a long time been acquiring some facts about the relationship of chemical analysis and crystal form, but it has only been since the discovery of X-ray analysis by Laue in 1912, that these speculations had much chance for verification. Hence the subject matter of these books is a recent addition to our knowledge of physics and chemistry.

The metallurgist's first problem was to de-



WHEN a user wishes steel for any particular application, he considers the physical properties which the steel must have. He usually has a choice of several steels. The consideration then quite logically narrows down to the *most economical* steel with which to meet the requirements.

For practically every known application, a Molybdenum-containing steel is available which is more economical than any other type of alloy steel. A broad claim? Yes. But a claim that is based, not on laboratory tests alone, not on isolated instances of practice — but invariably on repeated proofs in manufacture and in service . . . *on the merits* and general recognition of Molybdenum's outstanding qualities.

With "Moly" having, in the past few years, so broadly affected costs and service standards, it is a wise move of the manufacturer of alloy-steel products or the user of alloy-steel equipment and tools, to review his requirements; to consult the Climax engineers; and to learn for himself how money can be saved by standardizing on the more economical Molybdenum-containing steel having physical properties at least equal to what he is now using.

Continual Molybdenum developments have led to the publication of our house organ, "*The Moly Matrix*." A word from you puts you on our mailing list. A further request brings you these interesting books: "*Molybdenum in 1934*" and "*Molybdenum in Cast Iron — 1934 Supplement*." And for any alloy problem peculiar to your business, the services of our metallurgists and Detroit experimental laboratory are open to you. Climax Molybdenum Company, 500 Fifth Avenue, New York City. (In Canada: Railway & Power Engineering Corp., Ltd.)

CLIMAX Mo-lyb-den-um

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termine the space lattice in crystals of the various metals in as pure a state as possible. How this is done by X-ray methods occupies about half of Dr. Davey's volume. It is by no means simple; one might judge it would take a college senior of $\Phi\beta\kappa$ rank to get very far with these "elementary" matters. The much more difficult chemical problem is to determine the portion of (say) the aluminum, silicon and oxygen in the aluminum silicate crystal, a problem complicated by the fact that three common minerals, cyanite, sillimanite and andalusite have the same chemical composition, Al_2SiO_5. The crystal structure of compounds existing in common metals, like iron carbide in steel, are also quite difficult to analyze; solid solutions and intermetallic compounds (if such exist) are also of great difficulty but of prime interest to the metallurgical theorist. Matters such as these occupy the second half of Dr. Davey's volume, and are strong meat for postgraduates and research workers.

Dr. Hassel's little book on crystal chemistry summarizes the present views on topics related to those just mentioned. Prerequisite to its understanding would be a first reading of such a book as Davey's. It also spends much time on the question of atomic radii. (By the way, it is too bad the atomic physicists use so many common words like "radius." Atomic radius, for instance, implies that the atom is a sphere or at least a spheroid — rather a doubtful supposition for something which is either space or a field of force. But stop! the reviewer has committed the error he is decrying — note the words "space" and "field".)

. . . . . .

A FEW years back the International Tin Research and Development Council was set up by the principal producing countries, in an effort to increase the utility and consumption of the metal. Several technical bulletins describing researches it has sponsored have appeared, and now comes a popular account of "Tin Plate and Canning," which is very informative indeed. Copies may be had free by addressing L. J. Tavener, 149 Broadway, New York City.

The Truth About the Question Welding Vs. Riveting

RIVETING AND ARC WELDING IN SHIP CONSTRUCTION, by H. E. Rossell. 210 pages, 5x7¼ in. Published by Simmons-Boardman Publishing Co., New York. Price $2.25.

COMMANDER ROSSELL is as well qualified as any man alive to appraise the relative merits of these two types of joining mild steel in large and complex structures, for his active duty in the Construction Corps, U. S. Navy, spanned the time when riveting was supreme on the enormous dreadnaughts to the time when ounces were worth saving in trimming fighting ships down to weight limitations set by treaty, constructors were driven to adopt welding for a 20% weight saving and then turned to welded high tensile steel for an even lighter structure, equally strong. For some time now he has been professor of naval construction at Massachusetts Institute of Technology, and doubtless has had an opportunity to look at the main problem in a detached manner. It is therefore the more interesting to observe a certain partiality to the newer process; no effort is made to gloss over its present deficiencies, but neither is an effort made to whitewash the riveting method.

In fact the book is in no sense a partisan pamphlet — it is an extremely thorough and orderly discussion of the engineering design of joints. About half of the pages are devoted to riveted joints, half to welded. To a broad experience in the ship yards, Commander Rossell has supplemented the latest laboratory researches (and they have been many) into the reaction of either riveted and welded joints under load. Typical design problems are solved in detail, and the reviewer would judge that any designer of a large complex structure (not alone ships) would profit greatly from a study of this little manual. Its principal fault appears to be its lack of an index.

The author points out several important disadvantages of riveted joints which are readily removed by welding. Riveted joints are difficult to make tight and to keep tight, particularly oil tight (for faying surfaces then do not rust) and gasoline tight (for rivet heads corrode and loosen by the thousands). Riveted joints slip slightly

(Continued on page 76)

What to read

Iron Ore and Melting

Trend of Ore Treatment and Its Bearing on Lake Superior Iron Ore Reserves, Carl Zapffe, Paper for A.I.M.E. Feb. Meeting.

Modern Trend of Steel Melting Practice, T. M. Service, Iron & Steel Industry, Feb., p. 179 . . . . Pittsburgh Cooperative Studies — A Review, S. Epstein, Metals and Alloys, March, p. 71 . . . . Requirements of Scrap for Steel Making, R. A. Bull, Steel, March 18, p. 54.

Effect of Deoxidation on Some Properties of Steel, C. H. Herty, Jr., Transactions American Society for Metals, March, p. 113 . . . . Studies of Slags From Steel Furnaces (Abstract of Howe Memorial Lecture), E. C. Smith, Steel, March 18, p. 41 . . . . Non-Metallic Inclusions in Steel, S. F. Urban, Transactions American Society for Metals, March, p. 93 . . . . Sodium Carbonate in Iron and Steel Works, N. L. Evans, Metallurgia, Feb., p. 107.

Rotary Melting Furnaces (Brackelsberg), Walter Alberts, Heat Treating and Forging, Feb., p. 94 . . . . Rotary Melting Furnace Practice, S. E. Dawson, Foundry Trade Journal, Feb. 28, p. 155 . . . . Advances in Induction Furnace Design, W. Jackel, Engineering Progress, Feb., p. 44 . . . . Pulverized Fuel in the Metallurgical Industry, J. H. Mahler, Iron & Coal Trades Review, Feb. 22, p. 329.

Modern Tendencies in Blast Furnace Practice, L. P. Sidney, Iron & Steel Industry, Feb., p. 161 . . . . Notes on Development of Iron Blast Furnace, A. J. Boynton, Paper for A.I.M.E. Feb. Meeting . . . . Slack-Wind Blast Furnace Operation, F. M. Rich, Paper for A.I.M.E. Feb. Meeting . . . . Properties of Cold-Blast Pig Iron, J. E. Hurst, Foundry Trade Journal, Feb. 21, p. 137.

Insulation and Control of Open-Hearth Furnaces, W. C. Buell, Jr., Paper for A.I.M.E. Feb. Meeting . . . . Silicon Carbide Parts for Heat Exchanger or Recuperator, H. L. Read, Steel, Feb. 25, p. 39 . . . . Ladle and Teeming Practice in the Open-Hearth Department, G. D. Tranter, Paper for A.I.M.E. Feb. Meeting.

Manufacture and Properties of Bessemer Steel, C. C. Henning, Paper for A.I.M.E. Feb. Meeting.

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The Wrought Iron Problem of Today, James Aston, Paper for A.I.M.E. Feb. Meeting . . . . Wrought Iron by Aston Process, J. B. Nealey, Industrial Gas, March, p. 19.

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Rolling, Forging and Wire Drawing

Casting Metal Sheet and Rolling Direct, T. W. Lippert, Iron Age, March 21, p. 10 . . . . Flow Hardening in Cold Rolling, W. Trinks, Blast Furnace and Steel Plant, Feb., p. 139 . . . . Production of Black Plate in England, J. S. Caswell, Blast Furnace and Steel Plant, Feb., p. 121.

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THE BOOK OF STAINLESS STEELS

Send for These Pamphlets

Radiation Pyrometer

The Pyro radiation pyrometer for temperatures exceeding 1000° F. is a light-weight, handy, and simple automatic instrument made by Pyrometer Instrument Co. Its features, method of use, and applications are given in Bulletin Ax-37.

Safety in Oxwelding

A revised edition of "Precautions and Safe Practices" in the care and handling of oxy-acetylene equipment has been prepared by Linde Air Products Co. This booklet is regarded as a standard reference on this phase of safety in industry, and this latest edition contains some new suggestions required by advances in the oxy-acetylene process. Bulletin Mx-63.

Tubing Weight Tables

Timken Steel & Tube Co. has issued a series of "Master Weight Tables" for round steel tubing, on letter size heavy paper, punched for binding. Weights per lineal foot of length are given for all sizes of hot finished and cold drawn tubing. Bulletin Mx-71.

High Tensile Steels

Three types of high tensile steel particularly adapted to the transportation industries are described in a folder from U. S. Steel Corp. These are a chromium-copper-silicon steel for corrosion resistance, a medium manganese steel, and a strong structural silicon steel. Bulletin Mx-79.

Carburizing Steel

High strength and ductility, forgeability, and machinability, combined with superior case carburizing properties permit the attainment of maximum production with minimum cost. Such properties are obtainable in Jones & Laughlin's Jalcase steel. Bulletin Mx-50.

Turbo-Compressors

The new items in Spencer Turbine Co's bulletin are a new and smaller "Midget" turbo for individual mounting, a single-stage line which effects new economies, and the gas-tight turbos for acid and explosive gases. Bulletin Mx-70.

Metameter

Information on Bristol Co.'s Metameter, which makes it possible to control temperatures, pressures, levels, and other process conditions or operations at any distant place, is contained in Bulletin Ax-87.

Steel Shafting

Bliss & Laughlin has an attractive folder on their steel shafting, turned, drawn, ground, and polished to precision standards. Sizes and tolerances and uses are given. Bulletin Ax-42.

The Enduro Family

A new edition of Republic's booklet on the Enduro 18-8 family of stainless steels includes among other authentic data a table showing corrosion resistance in the presence of several hundred chemicals, solutions, and other reagents. Bulletin Mx-8.

Grinding Wheels

Norton Co.'s 59-page booklet is a complete handbook on grinding wheels. Wheel specifications, selection of abrasive and bond, and grinding wheel recommendations for all classes of work are included. Bulletin Ax-88.

Misco Alloys

Compositions, properties, and applications of Misco stainless, heat, and corrosion resisting castings are given in an illustrated folder offered by a pioneer producer, Michigan Steel Castings Co. Bulletin Mx-84.

Controlled Steels

Carnegie Steel Co. has published a very interesting booklet which describes in some detail the process control used in the production of uniform steels. Bulletin Je-85.

New Joining Process

Metal parts are joined cheaply, neatly and strongly by Electric Furnace Co.'s new, inexpensive nonoxidizing furnace atmosphere and their new, continuous brazing, coppering and soldering furnaces. Full details are given in Bulletin Ar-30.

Coated Electrodes

Murex heavy mineral coated electrodes are the subject of a well-conceived booklet prepared by Metal & Thermit Corp. Emphasis is laid on the metallurgical merits of a heavy, all-mineral coating. Many practical hints on welding are included. Bulletin Jr-64.

Tempering Furnace

Technical details and operating data on Lindberg Steel Treating Co.'s new Cyclone electric tempering furnace, which has shown a remarkable performance record in steel treating operations, are given in Bulletin Fx-66.

Moly Matrix

Climax Molybdenum Co.'s little monthly newspaper contains many interesting and informative articles. Get the latest issue by asking for Bulletin Ax-4.

Heat Treating Bath

A new folder on A. F. Holden Co.'s Light Case, which is showing savings of 10 to 20% for depths of case up to 0.010 maximum as compared to sodium cyanide, is available. Bulletin Ax-55.

Furnaces and Burners

All types of standard furnaces and standard burner equipment, particularly controlled atmosphere furnaces, are illustrated and listed in a folder by Surface Combustion Corp. Bulletin Ax-51.

Blast Cleaning

A centrifugal machine which cleans castings without the use of compressed air is the subject of Pangborn Corporation's new folder. How and why 1800 lb. of castings can be cleaned in 8 min. at low cost is told. Bulletin Jx-68.

Photocell Pyrometers

Recording potientiometers using a beam of light, a mirror galvanometer, and a photo-electric cell give instantaneous control with high sensitivity and accuracy. The different varieties made by C. J. Tagliabue Mfg. Co. are described in a 16-page letter-size booklet. Bulletin Fx-62.

Steels for Automobiles

The story of "Cold Finished Steel and the Automobile" is very interestingly told by Union Drawn Steel Co. Improvements in automotive design are reflected in improvements in cold drawn steels, the advantages of which are now available to many other industries. Bulletin Ax-83.

Nickel Silver

Seymour Mfg. Co. has a folder which gives the story of nickel silver—its historical background, preferred composition, applications, shapes available, and modern method of manufacture. Bulletin Ax-48.

Metallograph

A new 36-page booklet of E. Leitz, Inc., contains all information on the Leitz large Micro-Metallograph, MM 1. Excellent photomicrographs are reproduced to show its capacity. Special attention is given to the darkfield illumination feature. Bulletin Se-47.

Cyanides and Salts

R & H Chemicals Department of E. I. du Pont de Nemours Co. has a new 28-page manual on the procedure for case hardening, reheating, nitriding, and mottling of steels with cyanides, and on coloring, tempering, and drawing with salts. Nv-29.

Resistor Furnaces

Hevi Duty Electric Co. announces the first of a line of industrial furnaces using metallic resistor elements, permitting operating temperatures to 2300° F. in either oxidizing or reducing atmospheres. Bulletin Ax-44.

Heat Treating Machine

A new continuous machine for atmosphere heat treating is covered by an American Gas Furnace Co. bulletin. A variety of treatments may be performed by passing different atmospheres through the muffle. Description is complete and interesting. Bulletin Jr-11.

Stainless Steel Facts

Carpenter Steel Co. offers (to manufacturers in U.S.A. only) a booklet, designed in handy file folder form, presenting a wealth of data on Carpenter stainless steels. A good reference source of material. Bulletin De-12.

Electric Furnaces

Furnace users will find much valuable information in a recent publication of General Electric Co. which describes the construction and operation of G. E. electric furnaces. Many photographs, charts and drawings and a well written text make this booklet both interesting and instructive. Bulletin Jr-60.

Dark Room Layout

A novel card 9½x13 in. containing suggested arrangements for a photomicrographic dark room has been designed by Bausch & Lomb. Costs for installation are estimated, and on the reverse side are printed rules for using the dark room. Bulletin Jx-35.

Radium Radiography

Advantages of portability, ease of application and manipulation in examination of castings, forgings, molds, weldings, and assemblies are attributed to radium for industrial radiography. Details are given in a booklet issued by Radon Co. Bulletin Jx-56.

Neophot

"Neophot" is the name of a new metallograph of radically new design and universal adaptability. A pamphlet distributed by Carl Zeiss, Inc., gives its applications and features and is well illustrated with beautiful samples of micrographic work. Bulletin Jx-28.

New Hardening Method

The three vital factors in correct hardening are controlled by the new Vapocarb Hump hardening method, described in a Leeds & Northrup bulletin. These factors are quench point, heating rate and furnace atmosphere. Bulletin No-46.

Screw Machining

Screw machine products of aluminum are treated in authoritative and extensive manner in a booklet of Aluminum Co. of America. Besides general data on screw machining, a number of very useful tables appear. Bulletin Ar-54.

X-Rays in Industry

General Electric X-Ray Co. has available a profusely illustrated brochure which gives the complete story of the industrial applications of X-Rays, the modern inspection tool. Bulletin Ma-6.

Reports on Firebrick

Babcock and Wilcox Company offer a very complete set of Service Reports on Insulating Firebrick. These reports contain valuable data on adaptability of refractories and savings possible. Bulletin Ob-75.

Heat Resisting Alloys

Authoritative information on alloy castings, especially the chromium-nickel and straight chromium alloys manufactured by General Alloys Co. to resist corrosion and high temperatures, is contained in Bulletin D-17.

Manual of Pyrometry

Brown Instrument Co. offers an elaborate manual which describes the 50 exclusive features of their potentiometer pyrometer. The book will greatly interest those who must maintain accurate temperature. Bulletin Jr-3.

Big-End-Up

Gathmann Engineering Co. briefly explains the advantages of steel cast in big-end-up ingots, showing the freedom from pipe, excessive segregation and axial porosity. An 82% ingot-to-bloom yield of sound steel is usual. Bulletin Fe-13.

Liquid Carburizing

E. F. Houghton's Perliton liquid carburizer is the subject of a 23-page booklet. Depth of case, speed of penetration, and other results are well illustrated with graphs and photomicrographs. Nv-38.

Heat Treating Manual

A folder of Chicago Flexible Shaft Co. contains conveniently arranged information on heat treating equipment for schools, laboratories and shops, and also illustrates the several types of Stewart industrial furnaces. Bulletin Ar-49.

New Indicating Pyrometer

The new indicating pyrometer of Foxboro Co. is described in a recently issued folder which gives full details of its construction and accurate operation. The potentiometer system of temperature measurement is employed. A feature is the placing of all adjustments on the front cover plate. Bulletin Jr-21.

Recuperators

Results obtained with Carborundum Company's recuperators using Carbofrax tubes are fuel savings, closer temperature control, faster heating, and improved furnace atmosphere. Complete engineering data regarding application to various types of furnaces are given in Bulletin Fx-57.

Everdur

Properties, applications and forms available of this copper-silicon-manganese alloy are described by American Brass Co. High strength and corrosion resistance, ductility, weldability, workability, and moderate price are some of the advantages featured. Bulletin Dc-89.

Testing with Monotron

Shore Instrument & Mfg. Co. offers a new bulletin on Monotron hardness testing machines which function quickly and accurately under all conditions of practice. Bulletin Je-33.

Alloy Castings

Compositions, properties, and uses of the high nickel-chromium castings made by The Electro Alloys Co. for heat, corrosion and abrasion resistance are concisely stated in a handy illustrated booklet. Bulletin Fx-32.

Carburizing Boxes

Driver-Harris Co. devotes a folder to Nichrome cast carburizing boxes. Physical properties at room temperature and under operating conditions are given, as are the advantages of Nichrome castings for such service. Bulletin Jr-19.

Electric Furnaces

The electric furnaces made by Hoskins Mfg. Co. are well presented in their latest catalog. Contents include data on 17 types of furnaces and some valuable information on Chromel resistance wires and thermocouples. Bulletin Sp-24.

Stainless Steel Uses

The wide range of applications of Allegheny Metal, best known of Allegheny Steel Co.'s corrosion and heat resistant steels, is pictorially covered in a new and interesting booklet. Bulletin Ob-92.

Metal Progress
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Effect of Quality of Surface on Toughness, A. V. de Forest, Iron Age, Feb. 21, p. 18 . . . . Brittleness in Steel, C. L. Shapiro, Iron Age, Feb. 21, p. 12.

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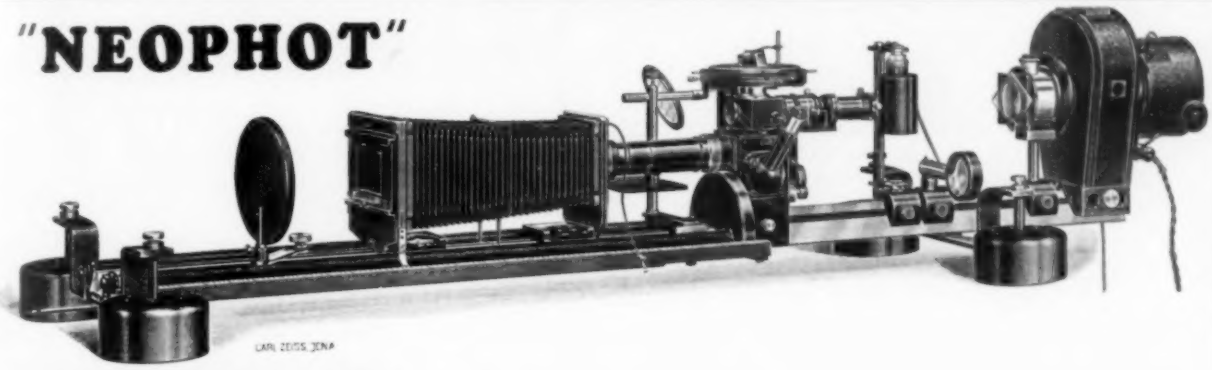
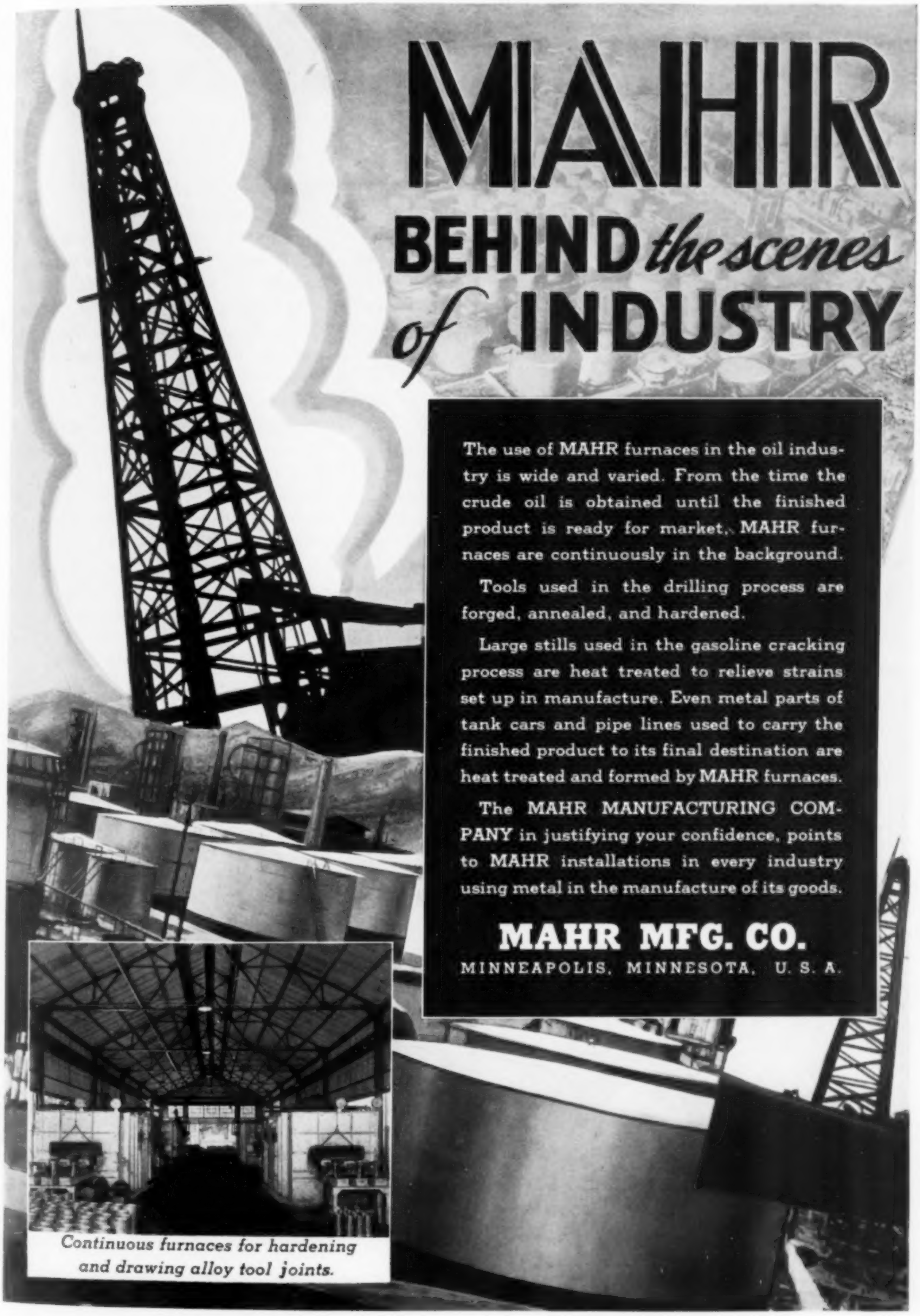


under heavy load, hence a continuous metal joint is stiffer. Much weight is saved by avoiding faying surfaces, straps, stapling members, and lazy legs on stiffeners. Continuity of strength at intersections and symmetrical and simple members are easily provided in welded construction; also the weakening by rivet holes is avoided.

On the other hand, welding has certain disadvantages which it would be fatal to disregard: In the first place the steel which can be welded into such large structures must be limited to those varieties which are not changed materially by the welding heat, and to those with high ductility in all conditions — high enough to yield under the internal stresses imposed by "welding shrinkage," for obviously these stresses cannot be relieved by annealing so large a structure. In Commander Rossell's opinion "the designer must choose, therefore, between the elmination of high tensile steel and the curtailment of welding" (an opinion, it may be stated, not shared by some metallurgists and naval constructors). He also presents the corollary that the all-welded ship is neither as desirable from an engineering view nor as cheap as one with riveting where seams are "fixed," in the sense that the part cannot move freely around its periphery. Weld metal of inferior quality is avoided by covered electrodes and skilled workmen. Inspection is no more difficult or uncertain in one system than in the other. Stress concentrations are more likely to occur in welded structures than in riveted ones, and the designer must be ever on his guard.

The effect of stress concentrations is most apparent in fixed or rigid joints, the standard example of which is a round patch in a large plate. Numerous failures are on record of spontaneous fracture in welded butt joints on plates which had previously been riveted into the structure before the welds were made. The author cites some palliatives, such as preheating, peening the joint, welding in "step-back" or "wandering" sequence. A complete section on shrinkage and warping warrants the study of every engineer who must design or make joints in really large structures, either in field or shop. Too many times it is forgotten that practices which are quite adequate for 8-in. pipe, for instance, will not be suitable for an 80-in. penstock.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Copper Steels

Precipitation hardening is effected by reheating the supersaturated solid solution of copper in iron for a period of time (determined by the condition of the steel and the temperature) within the range of 750 to 1245° F. The greatest hardness increase takes place on heating to from 840 to 930° F. for from 3 to 20 hr.; the longer time is required for the lower temperature.

The optimum changes in mechanical properties resulting from the precipitation hardening of normalized carbon steels containing 1.5% copper are shown in the last diagram. Tensile strength, yield strength and Brinell hardness increase; the reduction of area and elongation decrease on hardening, the effects diminishing as the carbon content of the steels increases.

Precipitation hardening in copper steels is seemingly unaffected by small quantities of other alloying elements, but it is by cold working.

Classification of Copper Steels

Copper steels may be classed as low copper, medium copper, and high copper steels.

The low copper steels are those containing only a few tenths per cent copper, it being added to enhance the corrosion resistance. The bulk of the tonnage of copper steels falls in this group. A bulletin from the Copper and Brass Research Association (1933) estimates that about 2000 tons of copper is used in steel annually in this country, largely for this purpose.

The medium copper group contains those steels having from about 0.5 per cent to several per cent of copper to effect specific changes in mechanical and physical properties other than corrosion resistance. In this group are included most of the copper and copper-manganese cast steels and a rapidly increasing tonnage of wrought steels, such as the "oil country tubing" containing about 1% copper, high tensile corrosion resisting steels containing chromium and copper, and molybdenum-copper steels of the age hardening variety promoted for welding.

The high copper steels are those in which the copper-rich, solid solution, epsilon, is a prominent structural constituent. Thus far this class has little industrial importance.